REPORT

ON THE

COST AND EFFICIENCY

OF THE

Heating and Ventilation of Schools.

FOR THE USE AND BY THE REQUEST OF

THE SCHOOL BOARD OF DUNDEE.

BY

THOMAS CARNELLEY, D.Sc. (Lond.), F.C.S.

PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF ABERDEEN, AND MEMBER OF THE SCHOOL BOARD OF DUNDEE.

[Assisted by JOHN FOGGIE, University College, Dundee.]

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CONTENTS.

	PAGES
REPORT	5—42
Introductory, and extent of information obtained	5—7
Methods of Heating and Ventilating usually adopted	7—9
First Cost	9—15
Annual Cost	15—26
Cost as affected by the size of the school	15—17
Consumption of Coal and cost per fire	17—19
Ditto per head of accommodation	19—21
Annual cost of Mechanical Ventilation	21—22
Comparison of various systems	22—26
Total Cost	47
Efficiency	26—40
Natural systems	26
Natural *v.* mechanical systems	27
Various methods of mechanical ventilation and heating ...	26—37
Harris Academy (special)	29—30
Air-filters	31—36
Reports as to efficiency from various School Boards	38—40
Advantages and disadvantages of the several systems	41—42
SUMMARY OF REPORT	43—48
RECOMMENDATIONS	49—52
APPENDIX I. Copy of information form	53
,, II. Table giving mean results of the various methods of heating and ventilating for each town	54
,, III. Table giving the mean results for the various towns, classified according to the mode of heating	55
,, IV. Tables showing the effect of efficient ventilation on the health and education of the children	56—60
,, V. Table showing the effect of frequently washing the floors of the school-rooms	60

REPORT

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HEATING AND VENTILATION OF SCHOOLS.

[*Note.*—Throughout this Report the accommodation in Schools is reckoned at 8 sq. ft. of floor space per head.]

To the Members of The Dundee School Board,—

Gentlemen,

On the 7th of May last you appointed a Committee to enquire into the subject which forms the title of this Report. As the Convener of that Committee I undertook to obtain the necessary information, and to make such experiments as would render that information as complete as possible.

For the purpose of this Report I have personally visited and have obtained detailed information from no fewer than 150 different schools, having a total accommodation for 111,000 children. These schools were, with but two or three exceptions, public schools under the Dundee, Aberdeen, Edinburgh, Newcastle, Leeds, and Salford Boards.

I have also obtained detailed information from 173 different schools (with a total accommodation, 165,000) under the Greenock, Bradford, Sheffield, Nottingham, Northampton, Leicester, Birmingham, and Liverpool Boards.

General information has also been obtained from the London, Glasgow, Accrington,* Govan, Finchley, Manchester, and Paisley Boards.

Finally, a number of experiments has been made in the mechanically ventilated schools in Dundee, Aberdeen, Govan, and Paisley, for the purpose of measuring the volume of air passing through the schools, the amount of gas consumed by the gas-engine, &c.; while experiments have also been made as regards the effect of filtering the air.

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* In this case from the Secretary of the Hargreaves Street Schools.

In the case of the schools not personally visited the information was obtained by sending a number of printed forms (see Appendix I.) to the Clerk of the several Boards with the request to fill them in as far as possible, there being one form for each school. As a general rule this has been done in a most satisfactory manner, and I therefore take this opportunity of thanking most cordially the various Boards for the efficient and ready manner in which they have supplied us with the information required. I would also include the Clerks of those Boards whose schools I personally visited, and who were in all cases most ready to give me every facility in obtaining information.

The data as regards the state of the air in the schools were taken from the following published papers :—

(1) Report to the Aberdeen School Board, by Brazier and Niven, "On the Ventilation in Certain Schools," 1885.

(2) "The Carbonic Acid, Organic Matter, and Micro-organisms in Air, more especially of Dwellings and Schools," by Carnelley, Haldane, and Anderson (Philosophical Transactions of the Royal Society, B4. 1887, Vol. 178, pp. 61—111).

(3) "Report on the Composition of the Air in the Schools under the Edinburgh Board," by Cosmo Burton, B.Sc. 1888.

(4) "Report on the Atmosphere of Twenty-six Buildings in Newcastle-on-Tyne," by Bedson, Lovibond, and Severn (North-Eastern Sanitary Inspection Association), 1888.

The data and information obtained from all the above sources have been very extensive, and the labour required, both for working these up, and for afterwards condensing the results into a practical form, has been very great indeed. The information has likewise come in piecemeal, and at somewhat long intervals; hence the considerable delay which has occurred in the appearance of this Report.

The details for each school are given in a series of MS. Tables, to which reference may be made if necessary; for the sake of convenience, however, the general results only accompany this Report, and are represented in Appendices II. and III.,* and in the Table on page 28.

In Appendix II. the mean results of the various methods of heating and ventilating are given in considerable detail for each town. The object of the Table is to allow the various systems adopted in a given town to be compared with one another without reference to other towns.

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* In all cases in which the caretaker of the school is provided with coal free, three tons of coal have been deducted from the total amount consumed annually, in order to make such schools as far as possible uniform with the others. A deduction of three tons is perhaps a little too small, but it is probably near enough for the purpose. Some few schools are used on Sundays. In these cases one-sixth of the coal used has been deducted.

In Appendix III. the mean results for the various towns are classified according to the mode of heating and ventilating. The object of this Table (which is much more condensed than Table I.) is to allow the several towns to be compared with one another, and also to compare the general averages of the different methods of heating and ventilating as derived from the results obtained in all the towns.

In the Table on page 28 are given the results of the measurements which have been made in the mechanically ventilated schools in Dundee, Aberdeen, Govan, and Paisley.

Of the various methods of heating, the one most extensively used is the system of large hot-water pipes (low pressure). Open fires are also a very favourite method; whilst all others are much less common. Thus, of the 311 schools examined in this respect,

- 147 * are heated by large low pressure hot-water pipes (chiefly in Birmingham, Bradford, Nottingham, Leeds, and Liverpool).
- 82 † are heated by open fires (more or less common in most towns. The Edinburgh Schools are heated exclusively by open fires).
- 32 are heated partly by open fires and partly by stoves (22 of these are in Leeds, and 8 in Leicester).
- 31 are heated by small high pressure hot-water pipes (20 of these are in Sheffield).
- 9 ‡ have adopted the mechanical system (Dundee and Aberdeen).
- 5 are heated by hot air (Salford only).
- 4 are heated by high pressure steam pipes (Sheffield and Newcastle).
- 1 is heated by low pressure steam pipes (Leicester).

Of the various methods of ventilating, the most common mode of admitting fresh air is by open windows, doors, &c., and also in many cases by Tobin's tubes; whilst the most usual outlet is the chimney of an open fire, or ventilators in the roof.

In some few schools, as in several in Aberdeen, the outlets consist of large wooden shafts running from near the floor up to the ceiling, and opening into roof ventilators, the inlets being Tobin's tubes or Sherringham's valves.

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* All the Glasgow Board Schools, some 70 in number, are also heated in this way.

† All the Manchester Board Schools are also heated by open fires.

‡ Schools in various other towns are also ventilated mechanically, but detailed results have not been obtained from these, as they have only been in operation for about a year or under.

In most of the Edinburgh Schools a form of open fire is adopted, known as the "Manchester Grate," in whieh fresh air passes through a heated tube behind the fireplaee and enters the room by a grating over the mantel, cold fresh air also entering the rooms by large Tobin tubes. The outlets consist of large gratings in the eeiling, opening into shafts passing to the roof. The ventilation may also be assisted by open sash windows.

In Glasgow Munn's patent ventilators are exelusively used, and are said to be satisfaetory, but whether this is the ease or not it is diffieult to say, as no analyses of the school air appear to have been made.

In Bradford they use Hill & Hayes' roof ventilators, and in Leicester Kites' roof ventilators, which the Clerk of that Board reports to be highly satisfactory. There are, however, no analyses in proof of this.

Meehanieal ventilation has been adopted in the following Sehools:—

Town.	No. of Schools.	Name of School.	System.	Kind of Air-Propeller.	Motive Power.	Mode of Heating, &
Dundee	2	Boy's High School Chem. Lab. Univ. Coll.	Blow in	Cunningham's modification of a Root's blower	Gas Engine	Blowing the air hot pipes, thence Tobin's tubes into rooms, the vitiatec passing out near floor by upright sl into Louvre ventil: in the roof.
,,	1	Ward Mills	ditto.	Large form of piston pump designed by Mr Cunningham	Water Motor	ditto.
,,	2	Harris Academy Girls' High School	ditto.	Blackman Fan	Gas Engine	ditto.
Aberdeen	3	King Street Rosemount Ashley Road	ditto.	ditto.	ditto.	ditto.
,,	1	Marywell Street	ditto.	A form of Cunningham's blower working with a fan-like motion	Water Motor	ditto.
Birmingham	2	Barford Road Upper Highgate St.	ditto.	Large revolving fan and air-propeller	Gas Engine	Air blown over pipes, thence thr inlet gratings intc rooms, and out at roof.
Paisley	1	Camphill	Exhaust	Blackman fan	ditto.	Hot-water pipes p round the rooms a floor. Fresh air mitted from outsic apertures at wi sills.
Accrington	1	New Jerusalem	ditto.	ditto.	ditto.	Hot-water pipes ning round the roc
Finchley	2	North End East End	ditto.	ditto.	ditto.	Air drawn out of r at top, fresh air c ing through gra behind a coil of pipes. Heating small high-pre pipes.
Govan	1	Hillhead	ditto.	Old form of Aland's fan, which is a modification of an ordinary winnowing fan	ditto.	Air drawn over water pipes, and ing out at ceiling.

Mechanical Ventilation is also employed in a number of Colleges and other public buildings. The School Board also intend to apply it to several new schools about to be erected in Leeds.

The heating and ventilation of a school are so intimately connected and so interdependent that the one cannot be treated apart from the other. In dealing with this question we have to consider—

(A) The First Cost;
(B) The Annual Cost;
(C) The Efficiency.

A. FIRST COST.

Information as to first cost can of course only be obtained directly from the Architect of the several schools. Owing, however, to the great time and trouble which it would require to make up statistics for each school as regards the first cost of heating and ventilation, apart from the cost of the general buildings and furnishings, it has been found possible to obtain reliable information only for Dundee schools, and for one new school in Aberdeen. The information in these cases is fortunately very complete. Further, as different architects are often employed by the same Board at different times, the estimates on the several schools would scarcely be comparable, owing to these architects not employing the same system in making up the estimates. This objection does not apply, however, to the Dundee schools, for Mr Langlands,* our architect, has made out the estimates in all cases, except that of the Girls' High School, and even in this case the same engineer was employed as in the other mechanically ventilated schools. Hence the Dundee schools are in this respect strictly comparable. The estimates for the different systems in Aberdeen were also drawn up by one architect, and are, in fact, estimates showing the relative cost of applying three different systems respectively to the Ashley Road School, which is just on the point of completion.

As regards first cost,† calculated per head of accommodation, Appendices II. and III. show:—

(1) That in naturally ventilated schools the cost of the ventilation is but a fraction of that of the heating, being about one-half in the case of open fires, rather more than one-third with large hot-water pipes, and rather more than one-fourth with small hot-water pipes. With mechanically ventilated schools this comparison cannot be made.

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* I am much indebted to Mr Langlands for the great service he has rendered me in the preparation of certain parts of this Report.

† "First Cost" includes the cost of everything which would not have been required had the school not been heated or ventilated at all.

(2) That even in schools ventilated on the same system the cost varies considerably. Thus, in Brown Street School the cost was only 1/1 per head; whilst in Balfour Street School it was 3/3, or three times as much, although these schools have almost exactly the same accommodation, and were built within a year of one another. Both these schools are heated by open fires. In schools heated by hot pipes, however, the cost is much more uniform, varying in large hot pipe schools from 6/2 per head in South Road to 8/8 in Hill Street; and in small hot pipe schools from 4/7 in Dudhope (new part) to 6/7 in Butterburn.

The first cost appears to be very uniform in the mechanically ventilated schools, varying from 22/- to 27/- per head in the Dundee schools which are ventilated on this system. In Aberdeen the cost, as will be shown below, is considerably less, being only about 16/6 per head.

(3) That the first cost per head does not seem to be materially affected by the size of the school, being pretty much the same for large as for small schools.

(4) That as regards the relative cost of the several systems, which is really the most important point as to first cost, there is unfortunately a very great difference between the data obtained in Dundee and those from Aberdeen. On this account, the data from these two towns must be considered separately, thus:—

	First Cost of Heating and Ventilating only. Dundee Schools.			Aberdeen Schools.		
	Per head.		Per 1000.	Per head.		Per 1000.
Natural Ventilation :—	s.	d.	£	s.	d.	£
Open Fires	2	5	121	10	0	500
Small hot-water pipes (high pressure)	5	8	286	11	7	582
Large hot-water pipes (low pressure)	7	5	371	...		...
Mechanical Ventilation	24	0	1203	16	6	826
	Calculated from the mean of several different Schools.			Estimates for heating the same School.		

According to the Aberdeen results, natural ventilation is much more, and mechanical ventilation much less costly (first cost) than in Dundee. The figures for Aberdeen have reference to the Ashley Road School, which is about being completed. Before adopting any system of heating and ventilating for that school, the Aberdeen Board obtained detailed estimates of the relative cost of applying the several systems to the school in question, and the above is the result. They ultimately adopted mechanical ventilation, and 16/6 is, I believe, the figure calculated from the tradesmen's specification estimates, and can therefore be relied on.

The 24/- per head for mechanical ventilation in Dundee is certainly higher than it would be in the case of a new Board School; for of the four Institutions which form the basis of the estimate, the Chemical Laboratory of the University College, owing to the purpose to which it is applied, requires a more efficient ventilation than an ordinary school, and many of the outlet flues had to be lined with lead to protect them from the action of acid fumes; whilst in both it and the Boys' High School the fans employed are much more costly (about £300 more) than a Blackman or Aland's fan. The engine power in the Harris Academy is more powerful than need be under ordinary circumstances, cf. p. 29. A 2 H.P. instead of a 3½ H.P. would have been quite sufficient; whilst in the College a 1 H.P. instead of a 2 H.P. would have been ample had the engine been required for ventilating purposes only, as in the case of an ordinary school. In the King Street and Rosemount Schools in Aberdeen also a 2 H.P. instead of a 3½ H.P. engine would have been sufficient.

The cost of the large inlet shafts, too, might also be largely reduced by a simpler construction and omission of the Louvre boards, which not only add to the cost, but reduce the efficiency of the fans. By adopting a form of school building such as that of the Ashley Road School in Aberdeen, to which mechanical ventilation may be more readily applied, the cost is very materially reduced; whilst the suitability of of the building for school purposes is not interfered with.

The Ashley Road School referred to consists of an oblong three-storey block, 109 ft. long by 84 ft. wide. There is a long central entrance hall running the whole length of the building, with class-rooms ranged on each side, and on the upper flats also at each end. The basement is excavated to a depth of about 7 feet,* forming a large fresh air chamber, a part of which contains the heating apparatus, gas engine, and fan. With a building constructed in this manner the arrangement and fixing of the air flues and shafts is much simpler, and the expense greatly curtailed.

As regards schools heated by small hot-water pipes (high-pressure) the difference in first cost between the Aberdeen and the Dundee figures is proportionately still greater than in the case of mechanical ventilation. This difference is in great part accounted for by the fact that the Aberdeen schools are more efficiently heated and ventilated than the corresponding schools in Dundee; for whereas in the latter there are only two rows of pipes in each room, there are three rows in each room in the former. The Aberdeen estimate also includes a very complete system of Tobin's tubes, and large upright shafts for vitiated air passing from near the floor to the ceiling, and thence to the roof, an

* Three feet of this would have been required even though mechanical ventilation had not been adopted.

arrangement which is not adopted in its completeness in any of the corresponding schools in Dundee.

With schools heated by open fires the difference in first cost between the Dundee and Aberdeen schools is even greater than in the case of the other systems. This difference is in part due to the fact that the estimate for the Aberdeen school is for a much more efficient system of ventilation than is employed in the Dundee schools. Further, Tables I. and II. show that the open fire schools in Dundee are insufficiently supplied with fires as compared with similar schools in other towns, thus:—

	Average No. of Pupils per Fire.
Dundee (mean of 8 schools) . . .	80
Seven other English and Scotch towns (mean of 59 schools)	60

In only one other town, viz. Newcastle, are there so many pupils (89) per fire as in Dundee, the next being Aberdeen with 65 per fire, Salford with 63, Edinburgh with 58, Leeds with 55, and Northampton and Liverpool with 54 pupils per fire. Consequently either the Dundee schools, which really need more heat owing to the more northerly climate, are insufficiently provided with fires, or else the schools in other, and on the whole more southerly towns are supplied with more fires than are necessary.

In those Dundee schools which are heated with large hot-water pipes, the amount of piping employed is considerably less than in the corresponding schools of the other towns examined; for whereas in all these other towns there are never less than two rows of pipes round each room, and frequently three, with sometimes a coil, there is usually only one row, and never more than two rows of pipes in the Dundee schools.

It must not therefore be forgotten that in comparing the first cost of the mechanically ventilated schools with that of the naturally ventilated schools in Dundee, we are doing so under conditions very unfavourable to mechanical ventilation, because, as shown above, mechanical ventilation has cost considerably more than it would do when applied to ordinary Board schools; whilst the first cost of the naturally ventilated schools has been considerably less than it would have been had these schools been heated and ventilated in a more liberal and efficient manner, such as they have adopted in Aberdeen and Edinburgh.

Taking the above facts into consideration, we may therefore state the relative first cost of the several systems, for which data are to hand as follows:—

		Cost of heating and ventilating *only*. Per head.	Per school of 1000 pupils.
		s.	£
Natural Ventilation.	Open Fires	4	200
	Small hot-water pipes (high pressure) ...	8	400
	Large do. (low pressure) ...	10	500
Mechanical Ventilation.	As applied to schools suitably designed	17	850
	As applied to ordinary schools ...	20	1000

To fit up a school for 1,000 children with mechanical ventilation would cost, therefore, from £400 to £700 (say £500) more than if one of the ordinary methods were employed, which on a loan at 4 per cent. would be equal to £20 a year, or about 5d. per head of accommodation. To have fitted up all the present schools in Dundee at first in this manner would have incurred an additional cost of about £270 a year, or less than the income of one headmaster.

The average total cost of accommodation per scholar for buildings and furnishings in all the schools which have been built by the Dundee Board is about £9. 5s.; whereas if mechanical ventilation had been applied, the cost, according to the figures given above, would have been about £9. 15s. per head.

The Harris Academy, which is ventilated mechanically, cannot be strictly compared with the other Dundee Board schools, for, being a secondary school, it differs from them in many points other than the mode of heating and ventilating. In Aberdeen, however, there are four schools under the Board which are ventilated mechanically, and which being elementary schools are, with one exception,* strictly comparable with the other schools. The last triennial report of the Aberdeen Board shows that the cost of the several schools which they have built was as follows:—

		Total Cost of Building and Furnishings (exclusive of Site) per head of accommodation at 8 square feet per head. £.	s.	d.
Natural Ventilation — Open Fires.	Ferryhill (1877)	10	1	8
	Skene Street (1878)	10	1	5
	Middle (1877)	9	10	0
	Causewayend (1877)	8	12	9
	Commerce St. (1876)	8	11	11
	Dr. Brown's (1879)	7	8	0
	Davidson's (1880)	6	15	5
		£8	14	5

		Total Cost of Building and Furnishings (exclusive of Site) per head of accommodation at 8 square feet per head. £.	s.	d.
Mechanical Ventilation.	Rosemount (1887)	10	0	2
	Ashley Rd. (1888)	9	2	3
	King Street (1883)	6	17	3
		£8	13	2

Note.—The date attached is approximately that of the opening of the School.

* This school was not built by but transferred to the Board, and adapted to mechanical ventilation.

The above table shows that in the case of the Aberdeen Schools the cost per head for schools ventilated mechanically was practically the same as for those heated by open fires, which, as already shewn, are by far the cheapest form of school as regards first cost. It is true, however, that the naturally ventilated schools were, on the whole, built at a more costly period than the mechanically ventilated schools; but the latter are much finer schools than the former, both as regards architecture and the nature of the accommodation provided. Indeed of the 150 schools which I have personally inspected in both English and Scotch towns, the Rosemount, and especially the Ashley Road schools in Aberdeen, appeared to me to be about the finest and most suitable for the purpose.

The following extract from a paper on "The Ventilation of Schools," read by Mr Hector, the Clerk of the Aberdeen School Board, at the Conference of School Board Clerks at Brighton in 1886, will be instructive and to the point:—

"As to cost, it may be stated that the expense of introducing the system of mechanical ventilation into the first school to which it was applied in Aberdeen was about £800, but a large part of this sum was spent in altering and adapting the building to the purpose after the plans had been so far carried out. In the second school the expense was about £600, and here again the amount included the cost of alterations and adaptations that might have been saved had the resolution to adopt the system been sooner arrived at. In the third school, to which the system is now being applied, the cost in excess of what would have been spent on ordinary appliances for ventilation will not much exceed £300, made up of the price to be paid for the gas-engine and the air-propeller, and for the construction of the various shafts and air-flues. At the rate paid by School Boards for the interest and repayment of school building loans, it will, therefore, be seen that the first cost for a large school (1,050 accommodation) amounts to little more than £12 a year for a term of 50 years, which is not a heavy price to pay for the benefits of the system. . . . . But by way of direct saving, it may be pointed out that *less lofty rooms are requisite in schools ventilated mechanically, so that, if even a foot of building can properly be dispensed with on the height of each floor of a school, the lessened cost would largely defray the introduction of the system.*"

The total cost of buildings and furnishings of schools (exclusive of site) in some towns other than Dundee and Aberdeen is as follows:—

	Average total cost of Buildings and Furnishings (exclusive of Site) per head of 8 square feet.
Newcastle (including a caretaker's house in each case).	
1 small hot-water pipe school (1885)	£7 6 8
5 large hot-water pipe schools (1876-1883)	8 8 9
2 open fire schools	9 11 6
Leeds.	
6 * large hot-water pipe schools (1874-1886)	£7 10 1
21 † stove and open fire schools (1874-1883)	8 14 2
15 ‡ open fire schools (1873-1884)	9 1 4
* 3 of these schools include a caretaker's house.	
† 5 of these schools ,, ,, ,,	
‡ 5 of these schools ,, ,, ,,	
Salford (exclusive of caretakers' houses).	
1 mixed system school (1885)	£6 7 4
1 hot air school (1885)	6 7 9
2 open fire schools (1880-1885)	7 1 9
1 large hot-water pipe school (1885)	7 12 8
Edinburgh (including a caretaker's house in each case).	
8 Manchester grate schools (1876-1886)	£8 16 3
5 ordinary grate schools (1875-1884)	10 14 1

B. ANNUAL COST.

(1.) *Annual Cost as affected by the size of the School.*—An inspection of the MS. Tables giving the results for each school shows:—

(*a*) That the average accommodation per school in Dundee is on the whole considerably less than the mean of all the other towns examined. Thus, the schools in Dundee heated by open fires have an average accommodation of 430; whereas the average for all the schools in other towns heated in the same way is 790, Nottingham alone being less than Dundee, viz. 364.

The Dundee schools, which are heated by large hot-water pipes, have an average accommodation of 666; whereas the average for all the other towns is 969, Salford alone being less than Dundee, viz. 507.

The only Dundee Board School (Harris Academy) which is ventilated mechanically has an accommodation of 1276, which is but slightly less than the average of the 4 mechanically ventilated schools in Aberdeen, viz. 1313.

On the other hand, the Dundee schools which are heated by small high-pressure hot-water pipes have an average of 814, which is slightly greater than that of the schools in other towns heated in the same way, viz. 775 (see Table II.)

(*b*) That in almost all cases (viz. in 74 out of 97) the annual cost per head of heating and ventilating is distinctly less in large than in small schools. This is rendered evident by the following table:—

AVERAGE COST PER HEAD IN PENCE.

(*Note.*—The numeral index attached to each datum indicates the number of cases of which the datum in question is the average.)

Accommodation.	Under 500.	500—750.	750—1000.	1000—1300	Above 1300
	d.	d.	d.	d.	d.
Dundee Schools—					
Open fires	4·3^{4}	2·4^{4}	......	......	......
Large hot-water pipes	4·5^{1}	3·2^{3}	3·3^{4}	......	......
Small ditto	8·7^{1}	1·3^{1}	3·3^{2}	2·7^{1}	......
Aberdeen Schools—					
Open fires	3·6^{4}	3·0^{4}	2·7^{3}	2·0^{1}	......
Small hot-water pipes	4·5^{2}	6·0^{2}	4·0^{1}	......	......
Edinburgh Schools—					
Ordinary grates } Open fires ...	7·3^{1}	5·5^{1}	4·6^{3}	......	......
Manchester grates } Open fires ...	......	......	5·0^{4}	4·5^{5}	2·7^{1}
Greenock Schools—					
Open fires	4·2^{1}	3·7^{3}	3·4^{3}	......	......
Large hot-water pipes	......	......	6·3^{1}	3·7^{3}	......
Newcastle Schools—					
Open fires	6·7^{2}	......	......	4·4^{2}	......
Large hot-water pipes	4·7^{1}	......	......	3·9^{5}	......
Small ditto	......	......	......	3·9^{1}	......
Leeds Schools—					
Open fires	7·3^{3}	6·0^{1}	5·4^{6}	6·0^{4}	5·5^{1}
Stoves and open fires	6·1^{3}	4·5^{3}	3·9^{11}	4·2^{2}	4·2^{3}
Large hot-water pipes	5·1^{3}	6·7^{4}	3·7^{3}	......	4·0^{3}
Sheffield Schools—					
Small hot-water pipes	10·0	......	10·0	......	8·2
Salford Schools—					
Open fires	3·9^{5}	5·9^{2}	......	......	......
Large hot-water pipes	4·5^{3}	6·5^{2}	......	......	......
Hot air	4·9^{3}	5·6^{1}	......	2·7^{1}	......
Mixed system	5·0^{1}	......	3·2^{1}	......	......
Nottingham Schools—					
Open fires	7·0^{2}	7·7^{1}	......	......	......
Large hot-water pipes and open fires	7·0^{1}	......	5·6^{1}	6·1^{2}	......
Large hot-water pipes	12·4^{2}	7·0^{4}	6·6^{11}	4·8^{2}	......
Leicester Schools—					
Stoves	5·7^{1}	5·4^{2}	5·5^{2}	6·0^{2}	7·0^{1}
Large hot-water pipes	......	6·3^{2}	......	4·5^{3}	3·5^{1}
Low-pressure steam coils	......	......	......	......	6·5^{1}
Northampton Schools—					
Open fires	......	......	8·5^{1}	6·5^{1}	......
Stoves and open fires	......	......	9·2^{1}	3·7^{1}	......
Small hot-water pipes	......	......	......	7·3^{1}	......
Liverpool Schools—					
Open fires	......	......	6·7^{1}	6·0^{2}	4·0^{1}
Large hot-water pipes	......	6·8^{3}	......	6·7^{4}	5·8^{10}

The Dundee schools being relatively small are therefore working at a comparative disadvantage as regards the annual cost of heating and ventilating.

The decrease in the annual cost of heating and ventilating, with the increase in the size of the school, is more especially noteworthy in the case of those schools which are ventilated mechanically, thus:—

Dundee.	Accommodation.	Annual cost of Heating and Ventilating per Head.	Aberdeen.	Accommodation.	Annual cost of Heating and Ventilating per Head.
		D.			D.
Boys' High School	2134	5	King Street	1580	4¾
Harris Academy	1276	9½	Rosemount	1050	7½
Chem. Lab. Univ. Coll.	1024	10½	Marywell Street	663	15½ or 12*
Girls' High School	683	13¼			

* A water motor is used in this school instead of a gas-engine, and it is very expensive to keep in repair. Had this not been the case the cost would have been about 12d. per head instead of 15½d.

It is, therefore, much more economical to work a large than a small school, and especially is this the case as regards mechanical ventilation.

(2.) *Annual Consumption and Cost of Coal per Fire in Open Fire Schools.*—The amount of coal consumed per fire and consequently the cost is very different even in schools in the same town, thus:—

	Consumption of Coals per Fire (Average).	Price per Ton (Average).	Cost per Fire (Average).
	Tons.	s. d.	s. d.
In Aberdeen it varies from 0·9 to 2·0 tons	1·1	12 5	15 2
In Dundee „ „ 0·8 * to 2·7 † „	1·5	12 1	18 4
In Edinburgh „ „ 1·5 to 2·8 „	2·0	11 0	22 6
In Liverpool „ „ 1·8 to 3·2 „	2·4	10 6	24 10
In Northampton „ „ 2·2 to 3·1 „	2·6	13 0	33 1
In Salford „ „ 2·1 to 3·8 „	3·0	8 3	24 5
In Leeds „ „ 3·1 to 5·0 „	3·8	7 0	26 6
In Newcastle „ „ 2·8 to 6·0 „	4·0	8 11½	35 9
Total Range ... 0·8 to 6·0 tons	2·6 (mean).	9 1 (mean).	23 6 (mean).

The above Table shows further, that in Newcastle four times as much coal is burnt per fire as in Aberdeen, and nearly three times as much as in Dundee. Although coal is very much dearer in Dundee and Aberdeen than in Newcastle and Leeds, yet the cost per fire is nearly twice as much in the latter as in the former towns. Indeed, the above figures, taken as a whole, show that the cheaper the coal the greater the quantity consumed per fire, and that the consumption increases very much more quickly than the price diminishes. The

* Wallacetown School. † Blackscroft School.

most extravagant school in Dundee (Blackscroft) burns less coal per fire than the most parsimonious school in Leeds or Newcastle. In the case of Aberdeen the difference is even still more marked. The most extravagant school in Newcastle burns nearly eight times as much coal per fire as the most parsimonious school in Dundee.

Either the children are being comparatively frozen in Dundee and Aberdeen, or they are being roasted in Leeds and Newcastle. But this represents only a part of the case; for not only is the amount of coal burnt per fire in Dundee very much less than that burnt in the more southerly towns, but, as pointed out above, the number of fires provided for a given number of pupils is also very much less, viz. one fire for every 80, as against an average of one fire for every 60 pupils in other towns. We have, therefore, $\frac{60}{80} \times \frac{1\cdot5}{2\cdot6} = \frac{3}{7}$, or on an average only 3 tons of coal are burnt in the Dundee schools for an average of 7 tons burnt in the six other Scotch and English towns which have been examined in regard to this point. We can therefore only conclude, either that they are very extravagant in these other towns, or that we are keeping the children much too cold in Dundee.

Stoves are used in only three of the towns examined, viz. Leeds, Leicester, and Northampton. In Leeds and Northampton both ordinary fires and stoves are employed in the same school in the ratio of about 3 to 2. As regards consumption and cost of coal, stoves appear to have a considerable advantage over ordinary open fires, thus:—

	Consumption of Coals per Fire (average).	Price per Ton (average).	Cost per Fire (average).
When Open Fires only are used :—	Tons.	s. d.	s. d.
In Northampton it varies from 2·2 to 3·1 tons.	2·6	13 0	33 1
In Leeds „ „ 3·1 to 5·0 tons.	3·8	7 0	26 6
Total Range ... 2·2 to 5·0 tons.	3·6	7 6	27 4
When 2 Stoves are used to 3 Open Fires :—			
In Northampton it varies from 1·5 to 2·5 tons.	2·0	12 11	26 5
In Leeds „ „ 1·9 to 5·4 tons.	3·0	7 0	20 9
Total Range ... 1·5 to 5·4 tons.	2·8	8 2	21 5
When Stoves only (mostly gill Stoves) are used :—			
In Leicester it varies from 2·8 to 4·5 tons.	3·5	10 0	35 2

In most cases, however, the headmasters stated that they much preferred open fires to stoves, as they were more cheerful and required less attention; whilst stoves were very liable to smoke if not properly looked after, and had a tendency to get out of order.

In Leeds and Northampton the stoves were used almost solely in the large halls; whereas open fires were used almost exclusively in the class-rooms.

(3.) *Annual Consumption and Cost of Coal per head of Accommodation (at 8 sq. ft. per head).*—Here again the difference is very great, not only as between different schools in the same town, but also as as between different towns, as shown by the following Tables:—

(*a*) *Open Fires*—

						Consumption of Coals per Head (average).	Price per Ton (average).		Cost per Head (average).
						lbs.	S.	D.	D.
In Dundee	it varies from	23 *	to	89 †	lbs.	42	12	1	$2\frac{3}{4}$
In Aberdeen	"	" 23	to	69	lbs.	42	12	5	$2\frac{3}{4}$
In Greenock	"	" 46	to	92	lbs.	69	9	$6\frac{3}{4}$	$3\frac{1}{2}$
In Edinburgh	"	" 47	to	122	lbs.	77	11	0	5
In Liverpool	"	" 70	to	118	lbs.	97	10	6	$5\frac{1}{2}$
In Newcastle	"	" 84	to	217	lbs.	101	8	$11\frac{1}{2}$	$4\frac{3}{4}$
In Salford	"	" 77	to	149	lbs.	104	8	3	$4\frac{2}{3}$
In Northampton	"	" 96	to	123	lbs.	107	13	0	$7\frac{1}{3}$
In Leicester	"	" 72	to	133	lbs.	111	10	0	6
In Leeds	"	" 104	to	239	lbs.	153	7	0	$5\frac{3}{4}$
In Sheffield	"	"				168	10	9	$9\frac{2}{3}$
In Nottingham	"	" 163	to	206	lbs.	195	7	0	$7\frac{1}{3}$
	Total Range,	23	to	239	lbs.	97 (average).	9	1 (average).	$4\frac{2}{3}$ (average).

Here we have very much the same result as in § 2, only still more marked. Thus, in Nottingham they burn nearly five times as much coal per head as in Aberdeen and Dundee, and although coal is not much more than one-half the price, yet it costs them nearly three times as much per head of accommodation. The most extravagant school in Dundee (Rosebank Sessional) or Aberdeen only burns about half as much coal per head as the most careful school in Nottingham. Surely there is something wrong somewhere, when one school in Dundee burns only 23 lbs., whilst one of the schools in Leeds burns 239 lbs. per head.

The consumption of coal per head leads to exactly the same conclusion as the consumption of coal per fire, viz. either that they are inordinately extravagant in such towns as Leeds, Sheffield, Nottingham, &c., or that we in Dundee and Aberdeen are freezing the children for the benefit of the ratepayers. In Dundee and Aberdeen we are burning only 42 lbs. of coal per head as compared with an average consumption of 111 lbs. per head in the 9 (or 10 including Leicester)

* Wallacetown School † Rosebank Sessional School.

other English and Scotch towns which have been examined, or in the proportion of 3 to 8. In other words, for every 1 lb. of coal we burn here, they burn nearly 3 lbs. per head in the other towns. Surely this is a great difference. And it is one depending not on the comparison of a few fires or schools, but of a large number, viz. of 20 schools, with 158 fires, and an accommodation of nearly 11,000 for Dundee and Aberdeen; and of 60 schools, with about 837 fires, and an accommodation of nearly 50,000 in the other 9 towns.

(*b*) *Large Hot-water Pipes (low pressure)*—

					Consumption of Coals per Head (average).	Price per Ton (average).		Cost per Head (average).
					lbs.	S.	D.	D.
In Dundee	it varies from	34 *	to 99 †	lbs.	51	12	1	3⅓
In Newcastle	" "	62	to 111	lbs.	83	8	9	4
In Leicester	" "	64	to 124	lbs.	86	10	0	4½
In Greenock	" "	64	to 141	lbs.	89	8	10½	4¼
In Liverpool	" "	83	to 181	lbs.	114	10	0	6
In Leeds	" "	57	to 262	lbs.	124	7	0	4⅔
In Salford	" "	86	to 171	lbs.	125	8	3	5½
In Birmingham	" "	—	—	—	136	8	6	6¼
In Bradford	" "	—	—	—	136	8	9½	6⅓
In Sheffield	" "	—	—	—	154	10	9	9
In Nottingham	" "	122	to 417	lbs.	175	7	0	6⅔
	Total Range,	34	to 417	lbs.	127	8	8	5¾

Here the results with large hot-water pipes (low pressure) are very similar to those with open fires, the several towns following very much the same order. In Nottingham they burn three-and-a-half times as much coal per head as in Dundee, and although coal is not much more than half the price, it costs them twice as much per head as in Dundee. Here again the most extravagant school in Dundee burns very much less than the most careful school in Nottingham. Again, whereas two schools in Dundee (Hawkhill and Clepington) burn only 34 lbs. per head, another school in Nottingham burns 417 lbs. per head, or more than twelve times as much. In Dundee (where we have 8 large hot-pipe schools, with a total accommodation of 5,327) we are burning only 51 lbs. per head as against an average of 136 lbs. per head in the 9 other towns examined, and in which there are 116 large hot-pipe schools, with a total accommodation of 106,991. Again, we may ask, Are we much too sparing of coal in Dundee, or are they much too extravagant in other towns?

* Hawkhill and Clepington Schools. † Glebe Lands School.

(*c*) *Small hot-water pipes (high pressure)*—

	Consumption of Coal per Head (average).	Price per Ton (average).	Cost per Head (average).
	lbs.	S. D.	D.
In Dundee it varies from 18 to 144 lbs.	52	11 11½	3⅓
In Aberdeen „ „ 34 to 156 lbs.	79	11 5	4¾
In Northampton „ „ ———	108	12 6	7¼
In Sheffield „ „ to above 174 lbs.	174	10 9	10
Total Range from 18 to above 174 lbs.	138	10 11¼	8

Similar remarks apply here to those made in *a.* and *b.* In Dundee we are burning on an average 52 lbs. of coal per head as against an average of 155 lbs. in the three other towns examined. The results obtained in *a.*, *b.*, and *c.* cannot be due to the superiority of the system of heating in the Dundee and Aberdeen schools; for the results apply equally to all the different systems, and are far too marked to admit of such an explanation. Indeed, they can only be due either to extravagance on the one hand, or to extreme parsimony on the other, or perhaps to both.

(*d*) *Small steam-pipes and coils (high pressure)*—

	Consumption of Coals per head (average).	Price per Ton (Average).	Cost per Head (Average).
	lbs.	S. D.	D.
Newcastle	83	8 9	4
Sheffield	162	10 9	9⅓
	142	10 5½	8
(*e*) *Small steam pipes and coils (low pressure).*			
Leicester	120	10 0	6⅓
(*f*) *Hot air.*			
In Salford it varies from 61—125 lbs. ...	94	8 3	4¼

(*g*) *Mechanical Ventilation and Heating.*—The following are the data as regards the coals for heating:—

	Consumption of Coals per Head (average).	Price per Ton (average).	Cost per Head (average).
	lbs.	S. D.	D.
In Aberdeen it varies from 45 to 73 lbs.	57	11 5	3½
In Dundee „ „ „ 63 „ 144 „	93	11 1	5½
Total Range, 45 to 144 lbs.	81 (average).	11 2 (average).	4⅗ (average).

The following are the data as regards the consumption of gas by the gas-engines for driving the fans :—

	Consumpt. of Gas per Engine.		Consumption of Gas for Engine per head of accommodation.		Price ℔ 1000 cb. ft.		Cost per Head (averge.)
	cubic feet.	(average) c. ft.	cubic feet.	(average.) cub. feet.	S.	D.	D.
In Aberdeen - -	......	61,600	39 to 59	47	3	7	2
In Dundee it varies from	52,500 to 89,200	66,800	25 to 83	52	3	8	$2\frac{1}{3}$
	Average	65,100	Average	$50\frac{1}{2}$	3	$7\frac{3}{4}$	$2\frac{1}{4}$

Including the annual cost of repairs and of oil for the engine, the total annual cost of mechanical ventilation per head is as follows :—

		Total Cost per Head.			Average.
In Aberdeen it varies from	...	$4\frac{3}{4}$d. to $7\frac{1}{2}$d.	...	...	6d.
In Dundee ,, ,,	...	5d. ,, $13\frac{1}{4}$d.	...	...	$8\frac{1}{2}$d.
		Total Range, $4\frac{3}{4}$d. to $13\frac{1}{4}$d.			Average, $7\frac{1}{2}$d.

The above figures show that they work mechanical ventilation more cheaply in Aberdeen than in Dundee, and that this difference is chiefly due to the smaller consumption of coal for heating purposes in the former town. The cost of gas for the engine, and the cost of repairs, oil, &c., though somewhat higher in Dundee, is nearly the same in both towns.

We may approximately apportion the annual cost of mechanical ventilation and heating as follows :—

Cost of Coal for Heating (at 11/2 per ton)	...	$4\frac{1}{2}$d.	per head of accommodation.
Cost of Gas for Engine (at 3/8 per 1000 cb. ft.)	...	$2\frac{1}{4}$d.	,, ,,
Cost of Oil for Engine	...	$\frac{1}{2}$d.	,, ,,
Cost of Repairs	...	$\frac{1}{4}$d.	,, ,,
		$7\frac{1}{2}$d.	

This is for a school of 1050 in Aberdeen, or of 1600 in Dundee.

As we have already seen, the annual cost per head of the mechanical system depends very largely on the size of the school, so that the larger the school, the smaller is the cost per head, being in fact almost in inverse ratio to the accommodation (see page 17).

(4.) *Comparison of the Cost of Various Systems of Heating.*—It is difficult to compare fairly the annual cost of the various systems of heating and ventilating with one another. This arises partly from the fact that the price of the same quality of coal varies in different towns, and partly from the fact that the liberality with which the coal is used, is also very different in different districts. As a rule, the cheaper the coal, the more freely is it used; indeed, the liberality in this respect increases more rapidly than the price of the coal

diminishes, so that, as pointed out above, it generally costs much more per head to heat a school in a town where coal is cheap than in one where it is comparatively dear. In making a correct comparison, therefore, we cannot take the average of the cost of the several systems in all the towns; but we must compare the cost of the several systems in the same town, irrespective of other towns, or we may take one given system as a standard, and assume that (supposing the price of coal and freedom with which it is used were the same in each town) the cost of this standard is the same in all the towns.

As a standard, it is necessary to take that system which is adopted in the greatest number of towns, and that is the system of open fires, which is used, more or less, in all the towns from which information has been obtained, except Bradford, Birmingham, and Leicester.

In the following comparison of the different systems, the cost of repairs, &c., is also included. In using the Table each town must be considered independently of other towns:—

otal Annual Cost per Head in Pence.	Dundee.	Aberdeen.	Edinburgh.	Greenock.	Newcastle.	Bradford.	Leeds.	Sheffield.	Salford.	Nottingham.	N'rthampt'n.	Leicester.	Birmingham.	Liverpool.
Open Fires	3	3	$4\frac{2}{3}$	$3\frac{2}{3}$	5	...	$5\frac{3}{4}$	$9\frac{3}{4}$	$4\frac{3}{4}$	$7\frac{1}{2}$	$7\frac{1}{3}$	...	...	$5\frac{1}{2}$
Stoves and Open Fires (2 to 3) . .	...	...	...	...	...	...	$4\frac{1}{4}$	...	...	...	$6\frac{1}{4}$	6	...	...
Large Hot-water Pipes (low pressure)	$3\frac{1}{2}$	...	...	$4\frac{1}{3}$	4	$6\frac{1}{2}$	$4\frac{3}{4}$	9	$5\frac{2}{3}$	$6\frac{2}{3}$	...	$4\frac{2}{3}$	$6\frac{1}{4}$	6
Small Hot-water Pipes (high pressure)	$3\frac{1}{2}$	5	...	...	...	...	...	10	...	...	$7\frac{1}{3}$	...	...	...
Steam Pipes (high pressure) . .	...	...	...	...	4	...	...	$9\frac{1}{2}$	...	...	...	...	...	...
Steam Pipes (low pressure) . .	...	...	...	...	...	...	...	...	...	...	...	$6\frac{1}{2}$	...	...
Hot Air	...	...	...	...	...	...	...	...	$4\frac{1}{4}$	...	...	...	...	...
hanical Heating and Ventilation .	$8\frac{1}{2}$	6	...	...	...	...	...	...	...	...	...	...	...	...
onsumption of Coals per Head in Lbs.														
Open Fires	42	42	77	69	101	...	153	168	104	195	107	...	...	97
Stoves and Open Fires (2 to 3) . .	...	...	...	...	...	...	110	...	...	...	88	111	...	...
Large Hot-water Pipes (low pressure)	51	...	...	89	83	136	124	154	125	175	...	86	136	114
Small Hot-water Pipes (high pressure)	52	79	...	...	...	...	...	174	...	...	108	...	...	...
Steam Pipes (high pressure) . .	...	...	...	...	83	...	...	162	...	...	...	...	...	...
Steam Pipes (low pressure) . .	...	...	...	...	...	...	...	..	...	..	...	120	...	...
Hot Air	..	...	...	...	...	...	...	...	94	...	...	...	...	...
hanical Heating and Ventilation .	93	57	...	...	...	...	...	...	...	...	...	...	...	...

Or if, for the purpose of eliminating both the effect of locality on the price of coal, and the liberality with which it is used, we assume that in all towns the cost of open fires is 3d., and the consumption of coals 42 lbs. per head of accommodation (*i.e.* the same as in Dundee), and the cost and amount of coal used by other systems in the same proportion, then we get the results given in the following Table:—

Total Annual Cost per Head in Pence.	Dundee.	Aberdeen.	Edinburgh.	Greenock.	Newcastle.	Bradford.	Leeds.	Sheffield.	Salford.	Nottingham.	Northampton.	Leicester.	Birmingham.	Liverpool.	Average.*
															D.
Natural Ventilation. Open Fires	3	3	3	3	3	...	3	3	3	3	3	...	...	3	3
Natural Ventilation. Stoves and Open Fires (2 to 3)	...	...	...	...	...	...	2¼	...	...	...	2½	2¼	...	...	2¼
Natural Ventilation. Large Hot-water Pipes (low pressure)	3½	...	...	3½	2½	?	2½	2¾	3½	2⅔	...	1¾	?	3¼	2$\frac{9}{10}$
Natural Ventilation. Small do. (high pressure)	3½	5	...	...	...	...	...	3	...	...	3	...	...	...	3⅖
Natural Ventilation. Steam Pipes (high pressure)	...	...	...	...	2½	...	...	3	...	...	...	...	...	...	2$\frac{9}{10}$
Natural Ventilation. Steam Pipes (low pressure)	...	...	...	...	...	...	...	...	...	...	...	2½	...	...	2½
Natural Ventilation. Hot Air	...	...	...	...	...	...	...	...	2¾	...	...	...	...	...	2¾
Mechanical Heating and Ventilation	8½	6	...	...	...	...	...	...	..	...	...	...	...	...	7½

Annual Consumption of Coals per Head in Lbs.	Dundee.	Aberdeen.	Edinburgh.	Greenock.	Newcastle.	Bradford.	Leeds.	Sheffield.	Salford.	Nottingham.	Northampton.	Leicester.	Birmingham.	Liverpool.	Average.*
															lbs.
Natural Ventilation. Open Fires	42	42	42	42	42	...	42	42	42	42	42	...	...	42	42
Natural Ventilation. Stoves and Open Fires (2 to 3)	...	...	...	...	..	...	30	...	...	...	34½	?	...	...	30½
Natural Ventilation. Large Hot-water Pipes (low pressure)	51	...	...	54	35	?	34	38½	50	38	...	?	?	49	40
Natural Ventilation. Small do. (high pressure)	52	79	...	...	...	...	...	43½	...	...	42½	...	...	...	50½
Natural Ventilation. Steam Pipes (high pressure)	...	...	...	...	34½	...	...	40½	...	...	...	...	...	...	39
Natural Ventilation. Steam Pipes (low pressure)	...	...	...	...	...	...	...	...	...	...	...	?	...	...	?
Natural Ventilation. Hot Air	...	...	...	...	...	..	...	...	38	...	...	...	...	...	38
Mechanical Heating and Ventilation	93	57	...	...	...	...	...	...	...	...	...	...	...	...	81

From the above it will be seen that the difference in annual cost between the various *natural systems* is not very great, ranging from 2¼d. in the case of "stoves" to 3⅖d. per head in the case of small high-pressure hot-water pipes, or from 30½ to 50½ lbs. of coal per head, supposing that the cost of coal and the liberality in using it is the same as in Dundee. A careful inspection of the Table shows, however, that the differences between the average cost per head are more probably accidental than due to any real difference in the cost of the various natural systems, except perhaps that "stoves" seem, on the whole, the cheapest, and small high-pressure water-pipes the dearest method.

The annual cost of mechanical ventilation is distinctly higher than that of any of the natural systems. This, however, is necessarily so; for since more air is driven through the school with the former, more coal will of course be required to warm it to a given temperature.

The comparative annual cost of the "mechanical" and "natural" systems may be stated thus:—

	Cost per head.	For a School of 1000 pupils.
Natural or ordinary system of heating and ventilating ...	2⅝d.	£11 9 2
Mechanical systems	7½d.	31 5 0
Difference ...		£19 15 10

Therefore, to ventilate and heat a school of 1,000 children mechanically it costs about £20 per annum more than by the ordinary methods.

* The information from Liverpool came to hand too late to be included in these averages.

It must not, however, be forgotten that *this comparison is made under conditions which are* MOST UNFAVOURABLE *to mechanical ventilation;* for it so happens that the two towns (Dundee and Aberdeen), from which statistics have been obtained, are the two which are by far the most careful in the consumption of coals under the ordinary systems. In the "natural" schools in Dundee the free use of coals is restricted by the fact that it has been the headmaster's interest to look sharply after the careful consumption of coals, since his share in the earnings of the school has been calculated only after deducting the cost of heating, lighting, and cleaning; whereas in the institutions which are on the "mechanical" system there is no such restriction. In Aberdeen, on the other hand, where both classes of schools are under the same rules as regards coal consumption, the difference in the annual cost of the two is very much less than in Dundee. Thus, the difference between the annual cost of the two systems in Dundee is about 5⅓d. per head; whereas in Aberdeen it is only about 2d. per head. If we could have obtained statistics of mechanical ventilation from towns in which coal is used more liberally than in Dundee and Aberdeen, we should certainly have found that the difference between the annual cost of the mechanical and the ordinary methods was much less than that represented above. Even in Aberdeen the mechanical system costs only 1d. per head more than the ordinary system of small high-pressure hot-water pipes.

Again, in Aberdeen mechanical ventilation and heating costs 6d. per head per annum, with coals at 11/5d. per ton, while in Edinburgh, with coals at only 11/- per ton, ordinary fires cost 5¼d per head; in Bradford, with coals at 8/10d. per ton, large hot-pipes cost 6½d. per head, or more than mechanical ventilation in Aberdeen, although coals in the latter town are much dearer; in Leeds, with coals at only 7/-, open fires cost 5¾d. per head; in Sheffield, with coals at 10/9d., open fires cost 9¾d., and large hot-pipes 9d. per head; in Nottingham, with coals at only 7/-, open fires cost 7½d., and large hot-pipes 6⅔d. per head; in Birmingham, with coals at 8/6d., large hot-pipes cost 6¼d. per head,—so that in Aberdeen and even in Dundee mechanical ventilation and heating costs considerably less than the ordinary methods in many other towns, although coals and gas in the latter are very much cheaper.

In a large school like that of the High School in Dundee, or the King Street School in Aberdeen, the mechanical system costs only 5d. per head, or less than the large hot-pipe system at the Glebe Lands School (5¾d.), or the small hot-pipe system in the Institution part of the Harris Academy (8¾d.), or the Butterburn School (5d.) These last-named schools are all under the Dundee Board.

The cost of the mechanical system would also compare more favourably with the ordinary methods in towns where gas is cheap; for nearly one-third of the cost of the former is made up of the cost of the gas required for the engine to drive the fans.

Finally, there is no doubt that in a sufficiently large school (say about 1500 accommodation) mechanical ventilation and heating would not cost more per annum than the ordinary systems, supposing that the heating of the latter was efficiently done. It is only in the smaller schools that the mechanical system is costly.

C. EFFICIENCY.

(*a*) *Of different Systems as determined from the Composition of the Air:*—

Natural Systems of Ventilation.—The analyses of the air of schools made in Dundee (by Drs. Haldane, Anderson, and myself), in Aberdeen (by Prof. Brazier and Dr. Thomson), in Newcastle (by Prof. Bedson), and in Edinburgh (by Mr Cosmo Burton), show that with those systems in which the rooms are heated by radiation rather than by conduction, the air is much more highly charged with micro-organisms than with those systems in which the rooms are heated more by conduction than by radiation. For explanation of this see a paper by Mr John Aitken on "Dusty Air" in the Philosophical Transactions of the Royal Society of Edinburgh. Thus, in the naturally ventilated schools examined the following results were obtained:—

	No. of Micro-organisms per litre of air.			
	Dundee.	Aberdeen.	Edinburgh.	Newcastle.
Open Fires—Ordinary Grates (here radiation is at a maximum and conduction at a minimum)	169	87	66	224
Open Fires—Manchester Grates } Inter-mediate	...	...	47	...
Large Hot-water Pipes (low pressure) } Inter-mediate	96	...	...	...
Small Hot-water Pipes (high pressure).—Here conduction is at a maximum and radiation at a minimum	85	35	...	190

In respect to the other impurities in the air no conclusion can be drawn as regards the relative efficiency of the several natural systems, except that for open fires Manchester grates are much more effective than ordinary grates, as shown by the results obtained by Mr Cosmo Burton in the Edinburgh schools, thus:—

		Carbonic Acid per 10,000.	Organic Matter.	Micro-organisms per litre.
Open Fires	Ordinary Grates (mean of 5 Schools) ...	16·4 ...	13·5 ...	66
	Manchester Grates (mean of 10 Schools) ...	13·6 ...	8·3 ...	47

Comparison of Natural with Mechanical Systems of Ventilation.—A comparison of the results obtained in naturally ventilated, with those obtained in mechanically ventilated schools (taken as unity), shows distinctly that the latter is far more effective, thus:—

Excess over Outside Air.	*Dundee Schools* (Carnelley, Haldane, and Anderson).		*Aberdeen Schools* (Braizer; Thomson).	
	Mechanically Ventilated.	Naturally Ventilated.	Mechanically Ventilated.	Naturally Ventilated.
Temperature . .	1	0·66	1	0·9
Carbonic Acid .	1	1·7	1	1·6
Organic Matter .	1	7·0	...	...
Micro-organisms .	1	9·2	1	7·2

· The above table shows that, notwithstanding the very great improvement in the purity of the air, the temperature is considerably higher in the mechanically ventilated schools than in those under the ordinary systems. To produce such an improvement in purity by the ordinary methods of opening windows, &c., would reduce the temperature to a very uncomfortable and dangerous degree.

Mechanical ventilation reduces the number of micro-organisms in the air, not merely during the time it is in action, but it has been proved to have also a very marked effect after it has been stopped and replaced by natural ventilation, this effect extending over a period of many days at least.

Mechanical ventilation also, as shown by Prof. Brazier in the Aberdeen schools, keeps the composition of the air more or less constant in the different parts of a room; whereas, with natural ventilation, it is liable to be much less pure at one part than another.

(*b*) *Efficiency of Various Methods of Mechanical Ventilation.*

The results given in the following table were obtained by actual measurements of the volume of air passing through the several buildings, and of the volume of gas (or water) consumed by the engine in driving the fans:—

	GAS ENGINES.									WATER ENGINES.	
	Girls' High School (Dundee).	Harris Academy (Dundee).	Rosemount School (Aberdeen).	King Street School (Aberdeen).	Ashley Road School (Aberdeen).	Camphill School (Paisley). [See Note 1.]	Hillhead School (Govan). [See Note 2.]	Chemical Laby. University College (Dundee).	Boys' High School (Dundee).	Ward Mills School (Dundee).	Marywell Street School (Aberdeen).
Description of Air Propeller	1 Blackman,* 4 ft. (blow in).	1 Blackman, 4 ft. (blow in).	1 Blackman, 4 ft. (blow in).	1 Blackman, 4 ft. (blow in).	1 Blackman, 4 ft. (blow in).	2 Blackman, 5 ft. and 2 ft. (exhaust).	1 Aland's Winnowing Fan (exhaust).	5 Cunningham's Fans (blow in).	6 Cunningham's Fans (blow in).	Cunningham's Air Pump (blow in).	2 Cunningham's Fans, old form (blow in).
Power of Engine (nominal)	2 H.P. Otto.	3½ H.P. Otto.	3½ H.P. Otto.	3½ H.P. Otto.	2 H.P. Stockport	4 H.P. Stockport	2 H.P. Otto.	2 H.P. Otto.	1 H.P. Otto.	?	....
No. of Inlet Air Shafts	1	3	2	1	....	1 (exit)	1 (exit)	2	2	3 (outlets)	2
Total Area of Entrance to Inlet Shafts in sq. ft.	37·9	34	20	21	....	12·5	14·8	38·2	50	8·5	8·8
Vol. of Air in cub. ft. drawn per minute	6,822	14,022	15,328	20,485	....	38,229	15,236	14,500	12,384	1,417	5,438
Consumption of Gas (or Water) per hour, in cub. ft. (or gallons)	36	56·9	40	40	....	126	48	43·7	33·3	(?)	458
Vol. of Air moved per cub. ft. of gas consumed	11,370	14,786	22,992	30,727	....	18,205	19,044	19,910	22,313	....	712 (per gallon of water).
Vol. of Air per hr. per head of accommodation	600	659	876	777	....		633	649	348 §	281	491
„ „ „ „ of number on roll	1,063	731	920	791	....		....	....	1,386	280	422
Vol. of Air per penny of total annual cost	71,000	103,000	178,376	248,923	....		....	128,000	102,000	....	67,810
Current Cost of 1,000,000 cb. ft. of Warmed Air	14d.	9¾d.	5½d.†	4d.†	....		....	7¾d.	9⅘d.	....	14¾d.
Vol. of Air in cb. ft. per hr. per £ of first cost	672	563	....	....	....		....	583	314	....	....
„ „ „ „ per £ per head of first cost	367,000	680,000	....	....	....		....	600,000	580,000	....	....
Approximate Time in mins. required to change the whole of the air in the School once	13	11	7¾	8½	....		9¾ (?)	8¾ ‡	20 §	17	16

* Working only about half speed.

† The small cost of these two Aberdeen Schools is mainly due to the smaller consumption of coal, and to a smaller extent to the somewhat less cost of repairs, &c., and of gas. The Dundee mechanically ventilated Schools are, however, warmer than the corresponding Schools in Aberdeen, due no doubt to the larger quantity of coal burnt in those in Dundee.

‡ Or in 10¾ minutes when the Laboratory is completed.

§ The cubic space per head is very large at the Boys' High School.

Note (1). *Camphill School, Paisley.*—In this School there is a large central hall into which the vitiated air passes by wide apertures from near the ceiling of the various rooms. The fresh air enters the rooms from outside by openings at the window sills. The windows also open freely. A Blackman fan (5 ft. diam.), driven by a Stockport gas-engine of 4 H.P., extracts the impure air from this central well. A smaller fan (2 ft. diam.), driven by the same engine, is to be put in for ventilating the Science Department on the top flat. The School is heated by hot-water pipes, placed round the rooms above the floor. There are two boilers for circulating the hot water throughout the four flats. The heating apparatus is capable of raising the temperature to 70—76°. Both heating and ventilating apparatus have proved very efficient and thoroughly satisfactory. This is said to be the largest Board School in Scotland, there being accommodation for nearly 2000 pupils. The building is of three stories.

Note (2). *Hillhead School, Govan.*—This School is ventilated on the exhaust system by an old form of Aland's fan, placed in the attic. This fan is simply a modification of the ordinary winnowing fan, the air being drawn in at both sides of the axis of the fan and delivered off by the blades, which are arranged concentrically round the boss or hub. This School is heated by large hot-water pipes, over which the incoming fresh air passes. It is worthy of remark that the temperature over all the School was almost perfectly constant, viz. 58° F.

In connection with the above Table we may make the following remarks :—

(1). That water-engines are much more expensive, and far less efficient, than gas-engines as a motive power for driving the fans.

(2). That there is something wrong with the ventilating and heating arrangements in the Harris Academy, the volume of air moved per cubic foot of gas consumed being only 14,786 cb. ft.; whereas in the other schools which use the same power of engine and a Blackman fan of equal size, the volume of air moved for the same consumption of gas is 20,490 and 30,727 cb. ft. respectively. The fan at the Harris Academy is therefore doing only about one-half of its proper work. It is also driving far less air per consumption of gas than the Cunningham fans in the Boys' High School and the Chemical Laboratory of University College. Further, 1,000,000 cb. ft. of warm air costs 9¾d. at the Harris Academy, whereas the same volume costs only 5½d. and 4d. respectively at the Rosemount and King Street Schools in Aberdeen, although the ventilation and heating of the Harris Academy is supposed to be on exactly the same principle as these two Aberdeen schools. The price of coal and gas is almost exactly the same in the two towns. The difference, therefore, must be due to some defect in the working or construction of the system at the Harris Academy. Indeed, the annual cost of working the heating and ventilation of the Harris Academy is just double that of the King Street School in Aberdeen, and that no matter whether we compare the annual cost per head of accommodation, or the cost per million cubic feet of warm air supplied to the school. This, therefore, needs looking to. It is apparently due, in part at least, to some defect in the engine; for whereas the same power of engine (3½ H.P.) in the two Aberdeen schools consumes only 40 cb. ft. of gas per hour, that in the Harris consumes 57 cb. ft. per hour; and, further, the Harris fan moves only 14,022 cb. ft. of air per minute, whereas those (of the same kind and size) in the two Aberdeen schools move 15,328 and 20,485 cb. ft. respectively in the same time; so that in each of the latter schools we have more air moved even with a smaller consumption of gas than at the Harris Academy.

In view of the unsatisfactory results which had been obtained at the Harris Academy, another series of measurements was made on December 3rd, when the condition of things was found to be even worse than it was before, thus :—

	Examination made Dec. 3rd.	Previous Examination.	Should be about
Vol. of air drawn per minute, in cub. ft. ...	18,598	14,022	15,000
Consumption of gas per hour, in cub. ft. ...	92·3	56·9	40
Vol. of air moved per cub. ft. of gas consumed	12,090	14,786	22,000
Current cost of 1,000,000 cub. ft. of *warmed* air	8⅓d.	9⅝d.	7⅝d.
Current cost of 1,000,000 cub. ft. of unwarmed air	4d.	3⅓d.	2¼d.

It is thus seen that the consumption of gas is excessive. The engine is taking an explosion at every two revolutions; whereas it should take one only in every four revolutions.

The air pressure in the air-chamber is abnormally great, viz. 15 oz. to the square foot,* which would seem to indicate great friction in the flues leading from the air-chamber to the rooms. Apparently the engine is trying to drive more air into the air-chamber than can get out by the flues, and is hence working against itself. The wear on the engine and fan will therefore be considerable.

The extra expense on the Harris Academy from the above cause, owing chiefly to the excessive consumption of gas by the engine, must be from £10 to £15 a year.

One grave defect at the Harris Academy is the great amount of friction caused by the Louvre boards at the entrance to the large inlet shafts. These should be removed at once, and doubtless by this alone a great improvement would be effected. On my recommendation the Aberdeen School Board have done this at their Rosemount School, where the amount of air passing was considerably less than at the King Street School in the same town, owing to the great friction caused by the Louvre boards at the former school, whereas the entrance to the flues was quite free and unobstructed in the latter school.

(3). In several of the schools a 3½ H.P. gas-engine is used; this is a greater power than is necessary. A 2 H.P. engine should be ample.

(4). The method of *blowing in* the air is preferable to the *exhaust* system, and for the following reasons:—(*a*). By the exhaust system sewer air and ground air are very liable to be drawn into the rooms; whereas the blow-in system has the opposite effect. This is very important as regards health. (*b*). By the exhaust system the fresh air enters where it can by windows and doors, &c., as well as through special openings, and thus tends to cause cold draughts; whereas on the other system the fresh air enters *only* by special flues, so that

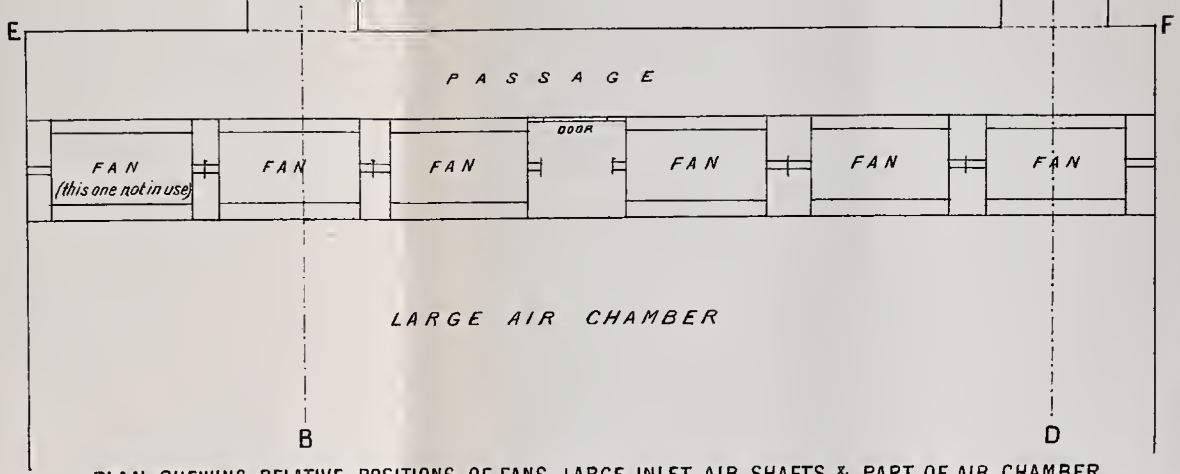
* The pressure in the air-chamber in the Chemical Laboratory of University College is only 5 oz. per sq. ft.

draughts are reduced to a minimum. (*c*). The incoming fresh air may be drawn from any desired position, and distributed much more effectively by the "blow-in" than by the "exhaust" system. (*d*) The "exhaust" system does not readily admit of the incoming air being filtered, whereas the "blow-in method" does.

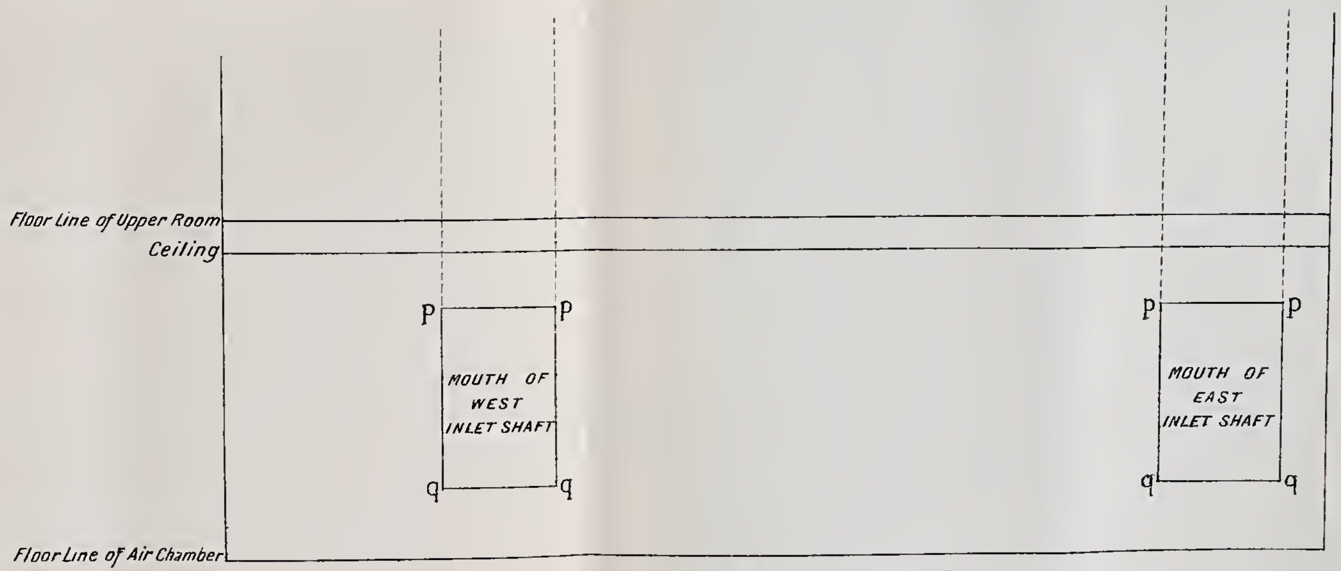
(5). One large inlet shaft is far more effective than two or three small ones, as the friction is very much greater in the latter, especially when a Blackman's fan is used. The entrance to the inlet shafts should be as free as possible, and all Louvre boards should be dispensed with.

The entrance to the inlet flues should be at least 12 or 15 ft. from the ground, so as to ensure the entering fresh air being as pure as possible. The entrance to the flue should be at the top and not at the side, by which means the friction is diminished and purer air is obtained. If it is thought necessary to place a cover over the shaft so as to prevent the access of snow, &c., it should be well raised above the mouth of the shaft, and the entrance to the shaft should be from all sides, except that next the building.

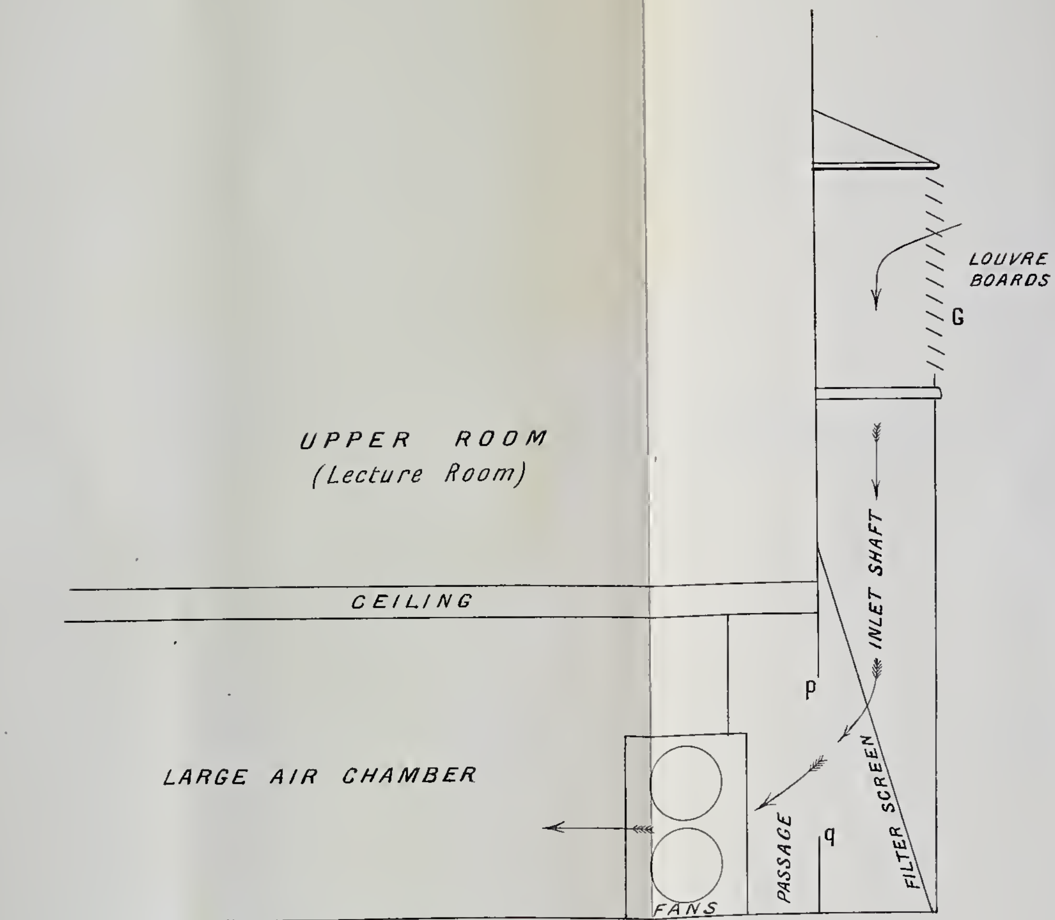
(6). The incoming fresh air should be filtered by passing through coarse jute cloth stretched on frames across the air-chamber. This is very effective, and the cost a mere trifle. The most suitable jute cloth is known as Light Hessian. It weighs 6½ oz. per yard of 40 inches wide, and costs 2d. per yard. It contains 67 meshes to the square inch, and is composed of threads whose diameter is one-fourth that of the mesh. If the filtering surface be sufficiently large, the amount of friction is quite inappreciable. In fact, paradoxical as it may seem, the volume of air passing is actually increased by nearly 10 per cent. if the filters be suitably arranged. This was proved by a series of experiments made with the system of mechanical ventilation in use in the Chemical Laboratory of University College, Dundee. In this building the fresh air is blown through the rooms by a set of 6 Cunningham fans driven by a gas-engine. The fresh air enters from the outside by two large upright shafts, on leaving which it passes through the fans into the large air-chamber, and hence through flues containing hot pipes into the various rooms. The arrangement for filtering the air consists of coarse jute cloth, such as that described above, stretched upon a light wooden frame, forming a kind of screen. One of these screens, which were each 17 ft. long by 4 ft. wide, was placed diagonally down each of the large inlet flues. The following sketch represents the arrangement adopted:—



PLAN SHEWING RELATIVE POSITIONS OF FANS, LARGE INLET AIR SHAFTS & PART OF AIR CHAMBER.



SECTION THROUGH E F

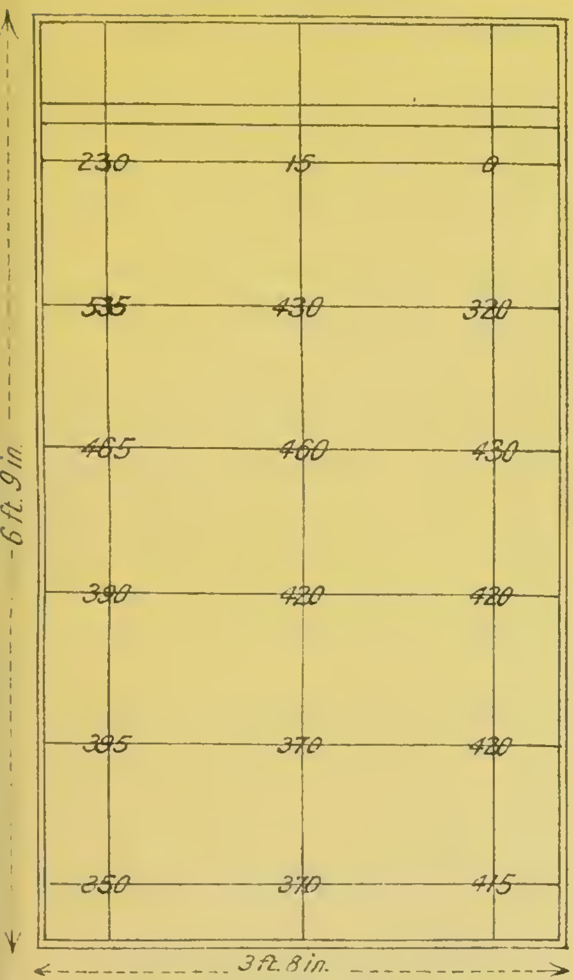


SECTION THROUGH LINE A.B. OR C.D.

The fresh air enters by the Louvre boards G. (these will shortly be taken out), passes down the large air-shafts, through the filter-screen, and thence by the opening p. q. into the passage on the outside of the fans, whence it is drawn through the latter into the large air-chamber, and so into the building. The experiments consisted in determining, by means of an anemometer, the amount of air passing through the two openings or mouths, p.p. q.q., of the two large inlet shafts. In the one set of experiments the amount of air passing was determined with the filter-screens in the position represented, and in the other set with the filter-screens removed. For taking readings the anemometer was suspended by a rod in any desired position in the mouth of the shaft. The following diagrams represent the readings obtained in these various positions —

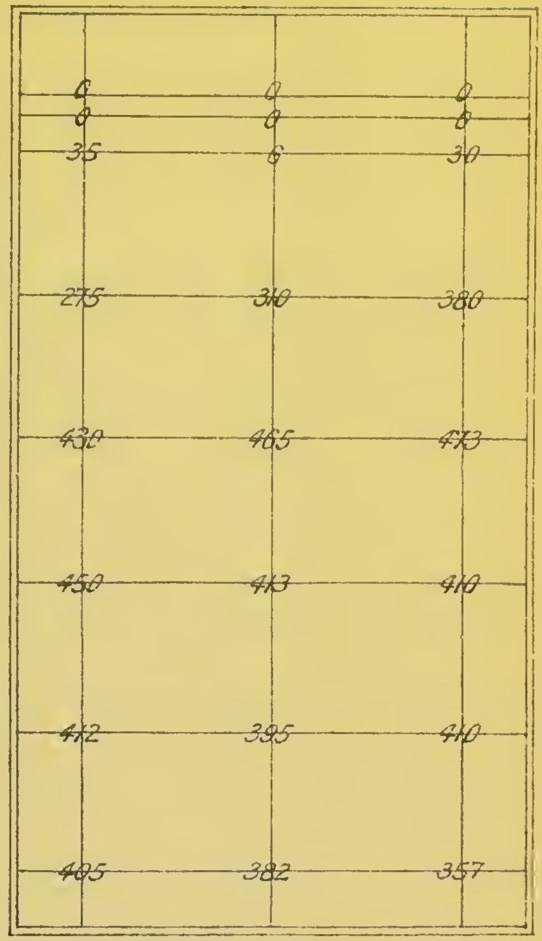
WITHOUT FILTER SCREEN

WEST SHAFT.



Average Velocity = 306 ft. per minute

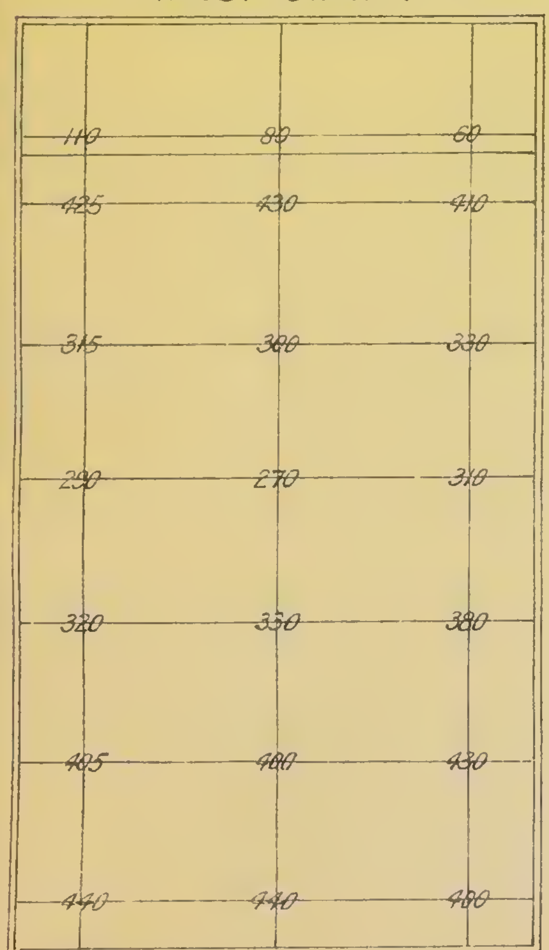
EAST SHAFT.



Average Velocity = 288 ft. per minute.

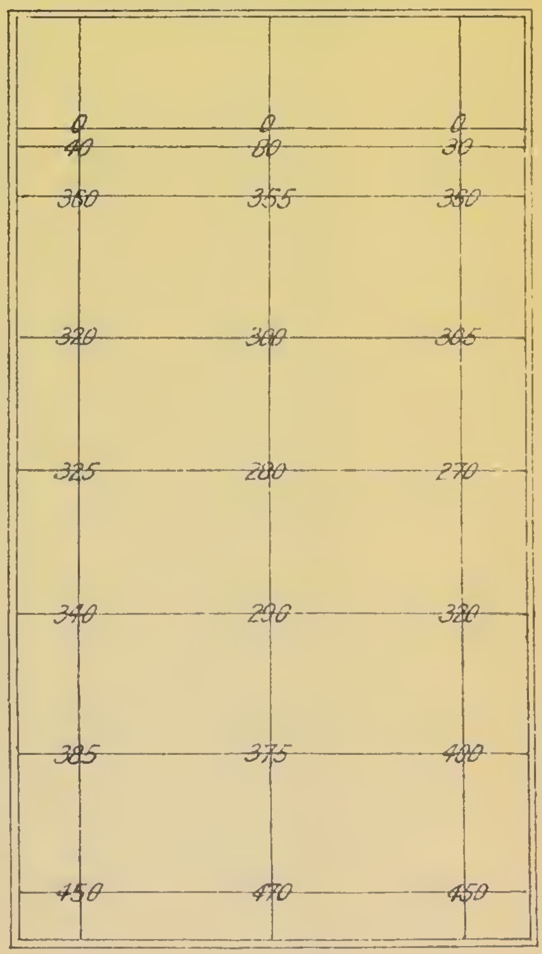
WITH FILTER SCREEN

WEST SHAFT.



Average Velocity = 327 ft. per minute.

EAST SHAFT.



Average Velocity = 309 ft. per minute.

Exactly similar results were also obtained in another pair of sets of experiments made on a previous occasion. These experiments, however, were not quite so exact as those given above, as in the latter a larger number of readings were taken. The main results of all the experiments made are given in the following Table:—

		West Inlet Shaft.		East Inlet Shaft.		Total of both Shafts.	
		Without Filter.	With Filter.	Without Filter.	With Filter.	Without Filter.	With Filter.
otal area of opening into shaft at Louvres in sq. ft.		50	50	50	50	50	50
ross section of shaft at smallest part, in sq. ft.		19	19	19	19	38	38
ffective area of mouth of shaft at p.p.q.q. in sq. ft.		21	21	21	21	42	42
rea of filtering surface, in sq. ft.		......	68	......	68	......	136
2nd Series of xperi-nents.	Vol. of air passing per minute, in cub. ft.	6,426	6,867	6,048	6,489	12,474	13,356
	Percentage increase in the vol. of air passing with the filters in use ...	......	6·9	......	7·3	......	7·1
1st Series of xperi-ments.	Vol. of air passing per minute in cub. ft.	7,056	8,158	7,980	8,788	15,036	16,946
	Percentage increase in the vol. of air passing with the filters in use ...	......	15·6	......	10·1	......	12·7

N.B.—The consumption of gas by the engine was carefully measured and found to be exactly the same, viz. :—42·8 cub. ft. per hour, no matter whether the air was passed through the filter or not.

This Table shows that filters arranged, as above described, not only do not diminish, but actually increase the volume of air passing. This increase amounts to nearly 10 per cent. on the average. This increase is somewhat paradoxical; but it is most probably due to the action of the filter-screens in preventing the formation of eddies, and to their causing a steadying of the air current, resulting in a more equal distribution of the current over the section of the shaft. This is seen to be the case by an inspection of the diagrams on page 34, which show that, *without the filter*, the volume of air passing through the centre of the mouth of the shaft is much larger than at the top or bottom; whereas, *with the filter*, the reverse is the case, the current being somewhat smaller at the centre, and much more equally distributed over the whole area of the mouth; this is especially noteworthy as regards the top of the mouth. Here, without the filter, the average velocity of the air at a distance of 14 inches from the top was only 53 ft.; whereas, with the filter, it was 390 ft. per minute: while at a distance of only 10 inches from the top there was a dead point, or slight negative current, without the filter; whereas, with the filter, the average positive velocity was about 67 ft. per minute. The velocity at the bottom of the mouth was also higher with than without

the filter, though the difference is not nearly so marked. Indeed, the results given in the above diagrams, showing the distribution of the air current, are most curious and interesting.

That the filters constructed and arranged, as above described, are effective in removing much of the solid impurities from the air passing through them, is shown by the fact that the dirt which had collected thereon after they had been in use for seven weeks was $2\frac{1}{2}$ lbs. This dirt consisted chiefly of soot and dust, and was very black and filthy looking. Had it not been for the filters the whole of it would have passed into the rooms, soiling the walls, furniture, &c.

The filters cost a mere trifle. Those which we used above had an area of 15 sq. yds., which, at 2d. a yard, cost only 2/6, with about 10/- in addition for the wooden frames. One set of filters will last a year, and require cleaning about twice in that time. The frames of course will last for years, so that 3/- per annum at the most should defray the cost of filtering the air in any school. The filters, however, far more than pay for themselves by the increase which they cause in the volume of air passing.

(7). *Comparison of Blackman's with Cunningham's fans.*—When *properly arranged*, as in the King Street and Rosemount schools in Aberdeen, a 48-in. Blackman fan appears to be more effective and less cost annually than 5 or 6 Cunningham fans, whilst the first cost is very much less, thus :—

	One 48-inch Blackman Fan (£25) driven by a $3\frac{1}{2}$ H.P. Otto Gas-Engine.	5 to 6 Cunningham's Fans (£55 each) driven by a 1 to 2 H.P. Otto Gas-Engine.	Aland's Winnowing Fan (£25) driven by a 2 H.P. Otto Gas-Engine.
	Mean of King Street and Rosemount Schools in Aberdeen.	Mean of High School, and Chemical Laboratory of University Coll., Dundee	Hillhead School, Govan.
Annual Cost per head (total) .	6d.	$7\frac{3}{4}$d.	
Cost per 1,000,000 cb. ft. of warmed air moved . . .	$4\frac{3}{4}$d.	$8\frac{3}{4}$d.	
First Cost of Fans and Engine (exclusive of flues, heating, fixing, &c. †)	£167 (about).*	£390 (about).	£130.
Volume of Air drawn per minute	17,906 cb. ft.	13,442 cb. ft.	15,236 cb. ft.
Volume of Air moved per cb. ft. of Gas consumed . . .	26,860 cb. ft.	21,156 cb. ft.	19,044 cb. ft.
[N.B.—The cost of Fans and Engines given above are the present prices.]			

* 2 H.P. gas-engine would have been quite sufficient, in which case the cost of fan and engine would have been only £130.

† The cost of fixing, &c., in the case of a Blackman or Aland's fan is considerably less than in that of Cunningham's fans, while the space required by the two former, and consequently the cost of building a chamber for the same, is also much less than in the case of the latter.

Note.—As pointed out above, the Blackman's fan in the Harris Academy does not compare at all favourably with the Cunningham's fans at the College and the High School, but this is probably owing to some defect in the arrangements. The Girls' High School has not been taken into consideration, because the fan there has only been running at about half-speed, the speed having been reduced by using larger pulleys.

(8). *Comparison of a Blackman's fan with an Aland's fan* (new form).—(*a*) On November 7th my assistant Mr John Foggie, accompanied by Mr Langlands, made the following measurements at Messrs Donald & Sons' works, Cadogan Street, Glasgow:—A Blackman's and an Aland's fan, each 2 ft. in diameter, were fixed and run on opposite ends of the same engine-shaft,* and anemometer readings taken in corresponding positions and at equal distances from the face of each fan. The mean of the readings was 598 ft. per minute over the area of the Blackman fan, and 1,216 ft. per minute over the area of the Aland fan, each fan moving at the rate of 830 revolutions per minute. This experiment proves that, when the fans are running at the same speed, the Aland fan drives about twice as much air as the Blackman, but gives no information as to the relative amount of power required to do it.

(*b*).

(9). The last item of the Table on page 28 shows that in all the schools which are mechanically ventilated, and for which the data are to hand, the whole air of the school is changed in about 15 minutes, or under. This was the degree of efficiency aimed at by Mr Wm. Cunningham of Dundee, who was the engineer for all the mechanically ventilated schools in Dundee and Aberdeen, and it has been well-attained in all cases, except in the case of the Dundee High School (Boys), which is the only one requiring a perceptibly long time, viz. 20 minutes, and in this school the cubic space per head is so large that a change as frequent as in the other schools, with less cubic space per head, is not needed.

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* The fans were about 8 ft. apart, and without any protecting screen between them.

REPORTS AS TO EFFICIENCY FROM VARIOUS SCHOOL BOARDS.

(*a*). *As regards Mechanical Ventilation and Heating* :—

Aberdeen (Four schools in this town are now mechanically ventilated).—The tests made by Profs. Brazier and Niven "confirm by scientific experiment the conclusion that any one visiting the schools would have arrived at by his ordinary senses; for it needs but a visit to any of the schools mechanically ventilated to perceive the comparative purity of the atmosphere, their freedom from draughts, and their equable temperature. In one of them it has recently been found necessary, in consequence of the operations connected with an enlargement of the building, to remove the ventilating machinery for a time, and to fall back in the summer weather upon the open windows for a supply of fresh air. The difference has been most perceptible. Imperfect diffusion of the entering air, stagnation of the atmosphere within the rooms, a heightened school odour, and an occasional grumble among the teaching staff at the changed condition of things, have been the result" (Paper on "School Ventilation" by Thos. Hector, Clerk to the Aberdeen School Board).

Govan (one school).—"Very satisfactory" (Letter from Clerk to the Board). "We are not aware of any building ventilated so effectually" (Report on Ventilation of this School by Messrs H. & D. Barclay to the Govan School Board).

Paisley (one school).—"The mechanical ventilation is working admirably. The school is most comfortable and healthy, chiefly owing to the excellent heating and ventilating apparatus" (Letter from Headmaster).

Accrington, Lancashire (one school).—"Very satisfactory" (Letter from the Secretary to the School).

Finchley (two schools).—"Quite satisfactory" (Letter from Clerk to the Board).

Birmingham (two schools).—"Satisfactory" (Letter from Clerk to the Board). In another letter the Clerk of this Board says that "mechanical ventilation has not worked perfectly, and it is still a question whether we have gained by its adoption anything equivalent to the expense."

Note.—The method of applying mechanical ventilation in these two schools in Birmingham seems to be quite different to that adopted in other towns, where very satisfactory results have been obtained. Indeed, the above letter from the Clerk to the Birmingham Board is the only case in which the thorough efficiency of mechanical ventilation has not been fully acknowledged. The conclusion is therefore that the arrangements in the two Birmingham schools must be defective in some respect.

Dundee (five schools).—As to these schools see page 27; also, paper by Carnelley, Haldane, and Anderson in the Philosophical Transactions of the Royal Society, 1887, on the "Air of Dwellings and Schools." The ventilation and heating of these five schools in Dundee are very satisfactory.

(*b*). *As regards Natural or Ordinary Systems of Heating and Ventilating*:—

*Nottingham.**—"On the whole we are satisfied with the hot-water apparatus," *i.e.* large hot-water pipes, low-pressure (Letter from Clerk to the Board). "Mann's ventilators in roof satisfactory." Ditto.

Glasgow.—System same as at Nottingham, "entirely satisfactory" (Letter from Clerk to the Board).

*Sheffield.**—"In schools now being erected the Board have decided to fix low-pressure hot-water apparatus, this having been found the most satisfactory heating power."

Leicester.—"Kite's roof ventilators are very satisfactory." "Flues connected with chimney-shaft very satisfactory" (Letter from Clerk to the Board).

London.—The following Report by the Engineer to the London School Board has been forwarded by the Clerk of that Board, and is of sufficient importance to be given in full:—

"Many of the Board schools are fitted with low-pressure hot-water apparatus. The general opinion with regard to warming the large schools of three and four floors in height is, that a well-arranged low-pressure hot-water apparatus is the best, both for economy in fuel, and also for efficiency in working. In the case of a school fitted with this apparatus, each floor has its own main and controlling valve, and each coil also is supplied with a valve. Ample boiler power is provided in excess of all ordinary requirements, as it is found that in nine cases out of ten the failure to obtain the necessary amount of heat is caused by the neglect of this necessary precaution.

"There are also in use several medium low-pressure apparatus working at high temperature (about 200° F., or a little below boiling-point), the average size of the pipes ranging from $1\frac{1}{2}''$ to $2''$, and radiating coils being also provided. This form of apparatus gives fair results.

"There are only a few cases of Perkin's system of high-pressure small-bore pipes, and this apparatus may be said to be working fairly well. Two schools are, however, now about to be warmed on this principle, and all the latest improved details of construction will be embodied in the apparatus.

"Several of the Board's schools are heated with low-pressure steam, and two new schools are being fitted with this system, the latest improvements in these cases also being adopted. No doubt is entertained but that this apparatus will give good results.

"In addition to the systems mentioned above, there are about twenty cases of hot-air apparatus. These have turned out a complete failure, and are being gradually removed, and the schools then warmed by hot water.

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* In reference to the above opinions it must not be forgotten that in Sheffield and Nottingham they use far more coal for heating than other towns, and consequently their expense is much greater. These opinions must therefore be taken with reserve.

It should be added that the failure of the hot-air apparatus takes place most frequently when an east wind is blowing, and this result is to a certain extent brought about from the want of mechanical power for the purpose of equal distribution.

"Ventilation is carried out by Tobin's pipes and extraction flues, and, in some instances, a series of hot-water pipes is carried up vertical shafts to draw off the vitiated air.

"In addition to the foregoing methods of warming the buildings, stoves, open grates, and gas radiators are very numerous. Heat produced in this way is, however, found to be very costly as regards fuel.

"The average temperatures given by the different kinds of apparatus are as follows:—

*Low-pressure hot-water - - -	50° to 60° F.
Steam - - - - - - -	55° to 65°
Open fires, stoves, and gas radiators -	38° to 40° and 45°

"W. J. Millington, Engineer."

From the above it will be seen that in London, Glasgow, Nottingham, and Sheffield, they all agree that large low-pressure hot-water pipes is the best of the ordinary systems of heating. None of them, however, have tried any mechanical method of heating and ventilating.

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* Much weight cannot be given to these numbers, as in comparing the heating efficiency of different systems it is not the *actual* temperatures, but the temperatures in *excess* of the outside air at the *same time* which must be compared. Indeed, the results given by Mr Millington for London Schools do not altogether accord with observations made in the Dundee, Aberdeen, and a few Newcastle schools, which were as follows:—

	Actual Temperature (average).	Temperature in excess of Outside Air at same time (average).
Open Fires (average of observations in 17 different Schools) .	53° F.*	16·8° F.
Low pressure hot water (do. in 9 different Schools) .	56	14·1
High pressure hot water (do. in 5 different Schools) .	58	13·8
Mechanical System (do. in 6 different Schools) .	58	20·5

* The average of 15 Edinburgh schools heated by open fires gave 61·5° F.

CERTAIN ADVANTAGES AND DISADVANTAGES OF THE SEVERAL SYSTEMS.

Open Fires.

Advantages— (1) More cheerful.

(2) First cost much less than hot-pipe systems.

(3) Keeps air fresher than hot pipes, owing to draught up chimney.

(4) So far as the Dundee schools are concerned, the temperature in the open fire schools was higher than in those heated by hot pipes.

(5) The rooms of these schools will probably need painting less frequently than those heated by other systems.*

Disadvantages—(1) Greater labour in service.

(2) Slightly greater annual cost than stoves, or steam-pipes, or large hot-water pipes (see pages 23, 24).

(3) Unequal distribution of heat.

(4) Air more highly charged with micro-organisms.

Stoves.

Advantages— (1) Smallest first cost.

(2) Least annual cost.

(3) Probably more effective heaters than open fires.

Disadvantages—(1) Greater labour in service.

(2) Require more attention than open fires.

(3) More liable to smoke than open fires.

(4) More liable to get out of repair than open fires.

(5) Not so cheerful as open fires.

Hot Pipes.

Advantages— (1) Less labour in service than either open fires or stoves.

(2) The class is not disturbed as in the case of the mending open fires and stoves.

(3) More equal distribution of heat.

(4) Air less charged with micro-organisms than when open fires are used.

(5) On the whole the annual cost is probably *slightly* less than with open fires, but more than with stoves.

Disadvantages—(1) Not so cheerful as open fires.

(2) First cost much more than in the case of open fires or stoves.

(3) Air not so fresh as with open fires.

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* See Paper by Mr John Aitken on "Dusty Air" in the Philosophical Transactions of the Royal Society of Edinburgh for 1884, Vol. 32, p. 239.

Of Hot-pipe Schools.

(1) Small high-pressure pipes are cheaper in first cost than large low-pressure pipes.

(2) In those schools examined, the air was better in rooms heated by small high-pressure pipes than in those heated by large low-pressure pipes.

(3) It takes longer to get up the heat with large than with small pipes.

(4) Small pipes are less obtrusive in the rooms.

Mechanical Ventilation.

Advantages— (1) Much greater purity of air as regards all the constituents.

(2) Efficiency of ventilation much more independent of the weather; whereas, with other systems, the ventilation is worst when most needed.

(3) The schools are warmer.

(4) More equal distribution of heat and of fresh air.

(5) Very effective in diminishing the number of micro-organisms, not only at the time the mechanical ventilation is in operation, but also for a long time after it has been stopped.

(6) Reduces draughts to a minimum.

In fact, the mechanical system heats and ventilates far better in every respect than any other system, and is, therefore, far more conducive to health and comfort, and to success in teaching and learning (see Appendix).

Disadvantages—(1) Greater first cost.

(2) Greater annual cost (except in the case of very large schools).

(3) Though in a town where several schools were heated and ventilated mechanically, there would not need to be more than an ordinary caretaker in each of such schools, yet *one* of these should be a man who had some knowledge of gas-engines, &c., so that he could attend to any repairs which might be necessary. Such a man would require a somewhat higher wage than an ordinary caretaker. This, however, would amount to very little if distributed over a number of schools.

SUMMARY.

I. *Extent of Information on which this Report is based* (see pages 5-7) :—

	No. of Schools.		Total Accommodation.
Personally visited and detailed information from ...	150	...	111,000
Detailed information from	173	...	165,000
Total ...	323		276,000

In addition to the above, general information has also been obtained from the London, Glasgow, Manchester, Accrington, Finchley, Govan, and Paisley Boards.

II. *Most Common Methods of Heating and Ventilating* (see pages 7-9) :—

47 per cent. of the schools examined are heated by large low-pressure hot-water pipes, and 27 per cent. by open fires. All other systems are far less common.

With but comparatively few exceptions, the ventilation is by open windows and doors for inlets, and by the chimneys or ventilators in the roof for outlets.

III. *First Cost* (see pages 9-15) :—

(*a*). The first cost per head does not seem to be much affected by the size of the school (page 10).

(*b*). The "open fire" schools in Dundee, compared with those in other towns, appear to be much "underfired." Thus, whereas the general average in other towns is one fire to every 60 pupils, in Dundee there is only one fire to every 80 pupils. There is indeed but one other town (Newcastle) which exceeds Dundee in this respect (see page 12).

In the "hot-pipe" schools in Dundee the amount of piping supplied also appears to be considerably under that in other towns (see pages 11, 12). These facts must not be forgotten when comparing either the first, or the current cost of mechanically with naturally ventilated schools in Dundee; for the comparison is made under conditions which are unfavourable to mechanical ventilation (see page 12).

(*c*). *General Conclusions as to First Cost* (pages 13—15) :—

		First Cost of Heating and Ventilating *only* — Per Head of Accommodation.		Per School of 1000 Pupils.
		s.		£
Natural Ventilation.	Open Fires	4	...	200
	Small Hot-water Pipes (high pressure)	8	...	400
	Large do. (low pressure)	10	...	500
Mechanical Ventilation.	As applied to Schools suitably designed	17	...	850
	As applied to ordinary Schools ...	20	...	1000

In round figures it would cost from £400 to £700 (say £500) more to fit up a school for 1000 children with mechanical ventilation than if one of the ordinary methods were adopted. This on a loan at 4% would amount to about £20 a year, or 5d. per head of accommodation. To have fitted up in this manner all the schools presently under the Dundee Board would have incurred an additional cost of about £270 a year, or less than the income of one headmaster. Or putting it in another way, the average total cost of the buildings and furniture (exclusive of site) of all the non-mechanically ventilated schools which have been built by the Dundee Board is about £9. 5s. per head of accommodation; whereas the cost, according to the above figures, would have been about £9. 15s. per head had mechanical ventilation been adopted. Or to take an actual case, the average total cost (exclusive of site) of the eight naturally ventilated schools which have been built by the Aberdeen Board, has been £8. 5s. per head of accommodation; whilst the total cost of the three mechanically ventilated schools which they have built has been £8. 13s. per head.

We may, therefore, take it that mechanical ventilation costs from eight to ten shillings per head more more than the ordinary systems. (Compare also Extract from Mr Hector's paper on page 14.) This could be reduced by 1s. 6d. per head for each foot taken from the height of the rooms, and that without affecting the health or comfort of the children.

IV. *Annual Cost* (see pages 15-26):—

(*a*). In almost all cases the annual cost per head of accommodation for heating and ventilating is distinctly greater in small than in large schools. This is especially so with mechanically ventilated schools. The Dundee schools, which are relatively smaller than those in other towns, are thus working at a comparative disadvantage in respect of annual cost (see pages 15-17).

(*b*). The average consumption of coals per annum in all the "open fire" schools in the several towns examined varied from 0·8 to 6·0 tons per fire,—average 2·6 tons. The average for Dundee schools was only 1·5 tons, or considerably less than in any other town except Aberdeen, the average for which was 1·1 tons per fire. The average annual cost in all the schools of the several towns was 23/6d. per fire, with an average price per ton of 9/1d.; whereas the average cost per fire in Dundee was only 18/4d. per fire, although the average price per ton was 12/1d. Only Aberdeen falls below Dundee in this respect. Although coal is very much dearer in Dundee and Aberdeen than in Newcastle and Leeds, yet it costs them nearly twice as much per fire in the latter as in the former towns. The most extravagant school in Dundee burns less coal per fire than the most parsimonious school in Leeds or Newcastle.

If we also take into account the greater number of pupils per fire in Dundee, we find that only 3 tons of coal are burnt in Dundee schools as compared with an average of 7 tons burnt in the other Scotch and English towns which have been examined. We can, therefore, only conclude, either

that they are very extravagant in these other towns, or that we are keeping the children much too cold in Dundee (see pages 17, 18).

(*c*). Stoves appear to be much more economical than open fires (see page 18).

(*d*). If the cost and consumption of coal be reckoned *per head* of accommodation instead of *per fire*, a very similar but much more marked result is obtained, thus :—

		Consumption of Coal per Head of Accommodation.		
		Consumption of Coal per head (Average).	Price per ton (Average).	Cost per head (Average).
Ordinary Systems.	*Open Fires—*	lbs.	S. D.	D.
	In all the towns examined it varies from 23 to 239 lbs.	97 (111)	9 1	$4\frac{2}{3}$
	In Dundee alone it varies from 23 to 89 lbs.	42	12 1	$2\frac{3}{4}$
	Large hot-water Pipes (low pressure)—			
	In all the towns examined it varies from 34 to 417 lbs.	132 (136)	8 $3\frac{3}{4}$	$5\frac{3}{4}$
	In Dundee alone it varies from 34 to 99 lbs.	51	12 1	$3\frac{1}{3}$
	Small hot-water Pipes (high pressure)—			
	In all the towns examined it varies from 18 to 174 lbs.	138 (155)	10 $11\frac{1}{4}$	8
	In Dundee alone it varies from 18 to 144 lbs.	52	11 $11\frac{1}{2}$	$3\frac{1}{3}$
Mechanical Systems.	*Mechanical Ventilation and Heating—*			
	In Dundee and Aberdeen it varies from 45 to 144 lbs.	81 (57)	11 2	$4\frac{2}{5}$
	In Dundee alone it varies from 63 to 144 lbs.	93	11 1	$5\frac{1}{2}$

N.B.—The numbers in brackets in the second column represent the average consumption of coal for all the towns *excluding Dundee.*

In Nottingham (open fires) they burn nearly five times as much coal per head as in Dundee, and although coal is not much more than one-half the price, yet it costs them nearly three times as much per head of accommodation. The most extravagant "open fire" school in Dundee only burns about one-half as much coal per head as the most careful "open fire" school in Nottingham. One open fire school in Dundee burns only 23 lbs. per head; while one of the open fire schools in Leeds burns as much as 239 lbs. per head! One of the "large hot-pipe" schools in Dundee burns only 34 lbs. of coal per head; while one of the "large hot-pipe" schools in Nottingham burns 417 lbs. per head. Either then they are inordinately extravagant in such towns as Leeds, Sheffield, Nottingham, &c., and are roasting the children, or we in Dundee are freezing them for the benefit of the ratepayers. It is to be noted that the same thing occurs no matter what system of natural heating and ventilation is adopted. The result, therefore, cannot be due to any superior efficiency of our heating arrangements in Dundee (see pages 19-21).

(*e*). They work *mechanical ventilation and heating* rather more cheaply in Aberdeen than we do in Dundee, thus (see pages 21, 22) :—

	Total Annual Cost per Head.		Average.
In Aberdeen it varies from	4¾d. to 7½d.	...	6d.
In Dundee „ „	5d. to 13¼d.	...	8½d.
	Mean	...	7¼d.

The annual cost of mechanical ventilation and heating may be approximately apportioned as follows for a school of 1000 children :—

Cost of Coal for Heating (at 11/2d. per ton) ...	4½d. per head of accommodation.		
Cost of Gas for Engine (at 3/8d. per 1000 cb. ft.) ...	2¼d.	„	„
Oil for Engine	½d.	„	„
Repairs	¼d.	„	„
Total ...	7½d.	„	„

The annual cost of mechanical ventilation per head depends very largely on the size of the school, being almost in the inverse ratio of the accommodation (see page 17).

(*f*). *Comparison of annual cost per head of different systems.*—The various "natural" systems scarcely show any difference from one another in respect of annual cost, except that stoves seem, on the whole, the cheapest, and small hot-water pipes (high-pressure) the dearest, method (see pages 22-24; also, Report by the Engineer to the London School Board on page 39).

The annual cost of the mechanical system is distinctly higher than that of any of the ordinary systems. The comparative cost may be stated thus :—

	Cost per Head.		For a School to accommodate 1000 children.		
	D.		£	S.	D.
Ordinary systems of Heating and Ventilating ...	2¾	...	11	9	2
Mechanical System	7½	...	31	5	0
	Difference	...	£19	15	10

Mechanical ventilation, therefore, costs about £20 more per annum for a school having an accommodation for 1000 children than the ordinary methods. It must not be forgotten, however, that this comparison is made under conditions which are most unfavourable to the mechanical system. If we could have made the comparison in other towns, which use coal more liberally than Dundee and Aberdeen, we should have found the difference very much less. Even in Aberdeen the mechanical system costs only 1d. per head per annum more than the ordinary system of small hot-water pipes (with regard to this point see pages 25, 26). In Aberdeen, and even in Dundee, the mechanical system costs much less than the ordinary methods in many other towns, although coals and gas in the latter are very much cheaper. In these towns they spend more in what appears to be an excessive use of coals with the ordinary systems than would more than pay for the extra cost of mechanical ventilation and heating, and do not obtain by any

means the great advantages they would have as regards health and comfort under the latter system.

In a large school like the Dundee High School (Boys), or the King Street School in Aberdeen, the mechanical system costs only 5d. per head, or less than such schools as those at Glebe Lands * and Butterburn,* or the Dundee Institution.

In a sufficiently large school (say from 1000 to 1500 accommodation) the annual cost of the mechanical system would not be more than in schools on the ordinary systems, supposing that the heating of the latter schools was efficiently done.

V. *Total Cost.*—Taking "first and annual" costs together, we have:—

	Cost per head of accommodation.			Cost for a School to accommodate 1000 Children.		
	Interest on First Cost.	Annual Cost.	Total Annual Cost	Interest on First Cost.	Annual Cost.	Total Annual Cost.
	D.	D.	D.	£	£ S. D.	£ S. D.
Ordinary Systems	3½	2¾	6	14	11 9 2	25 9 2
Mechanical System	8	7½	15½	34	31 5 0	65 5 0
Difference . .	5	4¾	9½	20	19 15 10	39 5 10

The difference in total annual cost (including interest on first cost) is, therefore, about £40 per annum for a school of 1,000 children. This is equal to 17/5d. a week more than the ordinary methods. In a school for 1,500 children this would be reduced to three-fourths of the amount, or to 13/6d. per week.

VI. *Efficiency, &c.* (see pages 26-40):—

(*a*). *Radiation* v. *Conduction.*—With those systems in which the rooms are heated by radiation rather than by conduction, the air is much more highly charged with micro-organisms than with those systems in which the rooms are heated more by conduction than by radiation (see page 26).

(*b*). *Manchester Grates* v. *Ordinary Grates.*—As regards open fires, "Manchester grates" are much more effective in keeping the air of the rooms pure than ordinary grates (see pages 26, 27).

(*c*). *Mechanical* v. *the Ordinary Systems.*—Mechanical ventilation and heating is undoubtedly far more effective in maintaining the purity and temperature of the air in schools than any of the ordinary methods usually adopted, and is hence more conducive to health and comfort (see page 27, also Appendix No. IV.)

(*d*). *Gas-engines* v. *Water-engines.*—Gas-engines are much cheaper and more effective than water-engines for driving the fans (see page 29).

* Schools under the Dundee Board.

(*e*). *Power of Gas-engine required.*—A 2 H.P.* gas-engine is amply sufficient for driving a 4 ft. Blackman or Aland fan; while a 1 H.P. is sufficient for 6 of Cunningham's fans.

(*f*). *Blowing in* v. *Exhausting the Air.*—The former is preferable (see pages 30, 31).

(*g*). *Inlet Shafts.*—One large fresh-air inlet shaft is much better than several small ones, and the entrance to the shaft should be as free as possible (see page 31).

(*h*). *Air Filters.*—When the incoming fresh air is filtered through coarse jute cloth to remove soot and dirt, the amount of friction introduced is so small as not materially to interfere with the volume of air passing through the school. In fact, if the filters are properly arranged, the volume of air passing is actually larger (nearly 10%) owing to the steadying of the air currents. The cost of such filters is a mere trifle, viz. 2d. per sq. yd., or not more than 3/- per annum, and they are very effective (see pages 31-36).

(*i*). *Blackman's* v. *Cunningham's Fans.*—When *properly arranged*, a 4 ft. Blackman fan appears to be more effective, and costs less, both in first and in annual cost, than the 5 or 6 Cunningham's fans usually employed to do the same work. Cunningham's fans are, however, more independent of the weather than either Blackman's or Aland's fans (see page 36).

(*j*). *Aland's* v. *Blackman's Fans.*—

(*k*). *Otto* v. *Stockport Gas-engines.*—

(*l*). *Time required to change the Air of a School by Mechanical Ventilation.*—By mechanical ventilation the whole of the air in a school may be easily changed in less than 15 minutes, and when the system is well-arranged, in less than 10 minutes (see page 37).

(*m*). *Harris Academy (Dundee).*—The engine, fan, and the large inlet air-shafts at the Harris Academy need attending to; for the measurements made show that they are not doing the full amount of work for the volume of gas consumed by the engine. The extra expense on the Harris Academy from the above cause must be from £10 to £15 a year (see pages 29, 30).

* Even a 1 H.P. would probably be sufficient.

RECOMMENDATIONS.

I. For *new* schools mechanical ventilation should be employed:—

First. Because it is more comfortable, the rooms being kept warmer, and the temperature more uniform and more equally distributed; whilst draughts are as far as possible avoided.

Second. Because it is much healthier, and prevents the spread of infectious diseases, owing to the rooms being supplied with purer air.

Third. Because the children by it are enabled to derive greater benefit from their education.

Fourth. Becauses it increases their grant-earning power without increasing the labour of earning the grant.

Fifth. Because it increases the teaching power of the teacher.

The extra cost entailed by mechanical ventilation over and above that of ordinary methods (including both annual expenses and interest on first cost) is about £39 a year in a school for 1000 children, or 9½d. per head of accommodation. For a school for 1500 children the cost would be only three-fourths of the above.

Part of the cost could be met quite easily by reducing the customary height of the rooms by one or two feet. This reduction in height would not at all detract from the health or comfort of the children. Thus, a reduction of the usual height of the rooms by one foot would, at 2d. per cb. ft., reduce the first cost of the school by about £70 on a school for 1000 children, or 1s. 6d. per head.

II. A 2 H.P. gas-engine should be used as a motive power for driving the fan.

III. A 48-inch fan should be used as air-propeller.

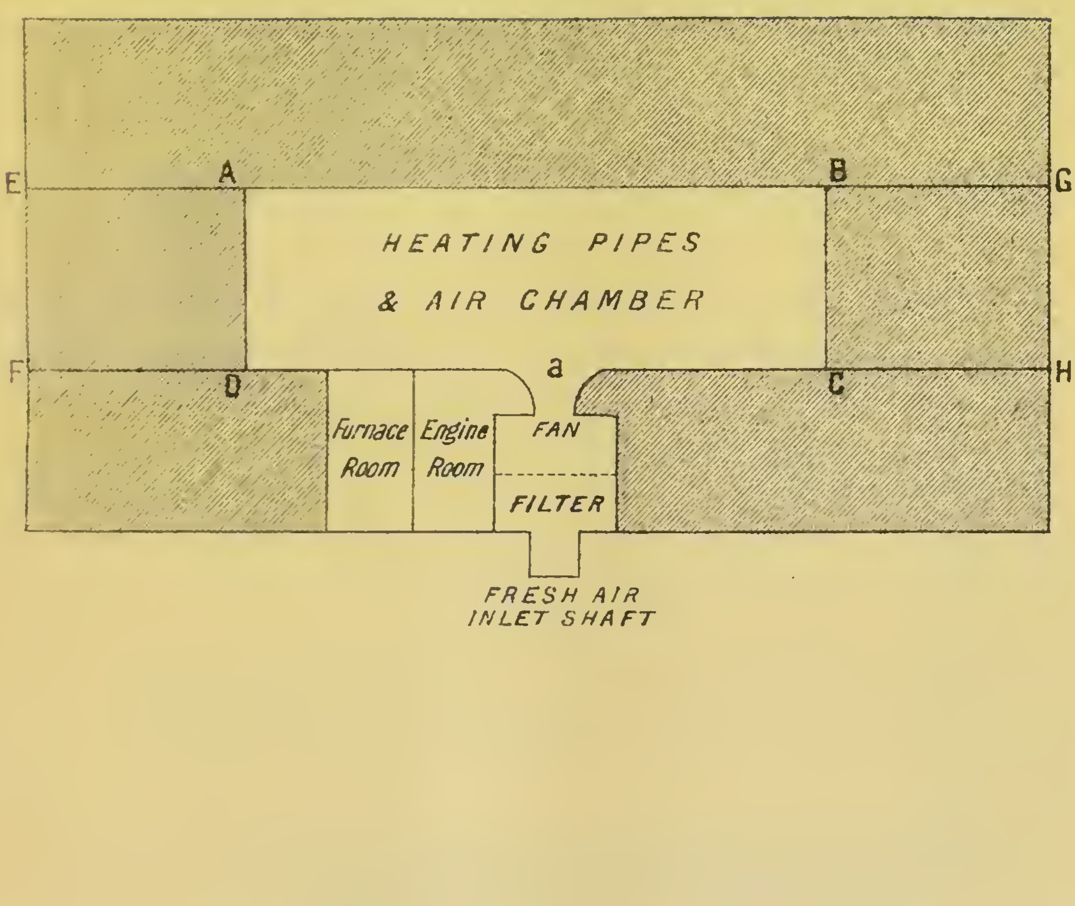
IV. The fresh air should be blown in and not sucked out of the school.

V. Perkin's high-pressure hot-water pipes should be used for heating.

VI. The heating pipes should be placed in the air-chamber and not in the flues. This would reduce the first cost.

VII. Arrangements should be made for mixing cold with the warm air, when necessary, before the latter enters the rooms.

VIII. For heating the hot-water pipes a brick furnace of the form suggested by our architect, Mr Langlands, should be adopted instead of the one more usually employed (see diagram facing page 51). This new form of furnace has given very good results in the only school (Victoria Road) in which it has been tried, and is correct in principle


E
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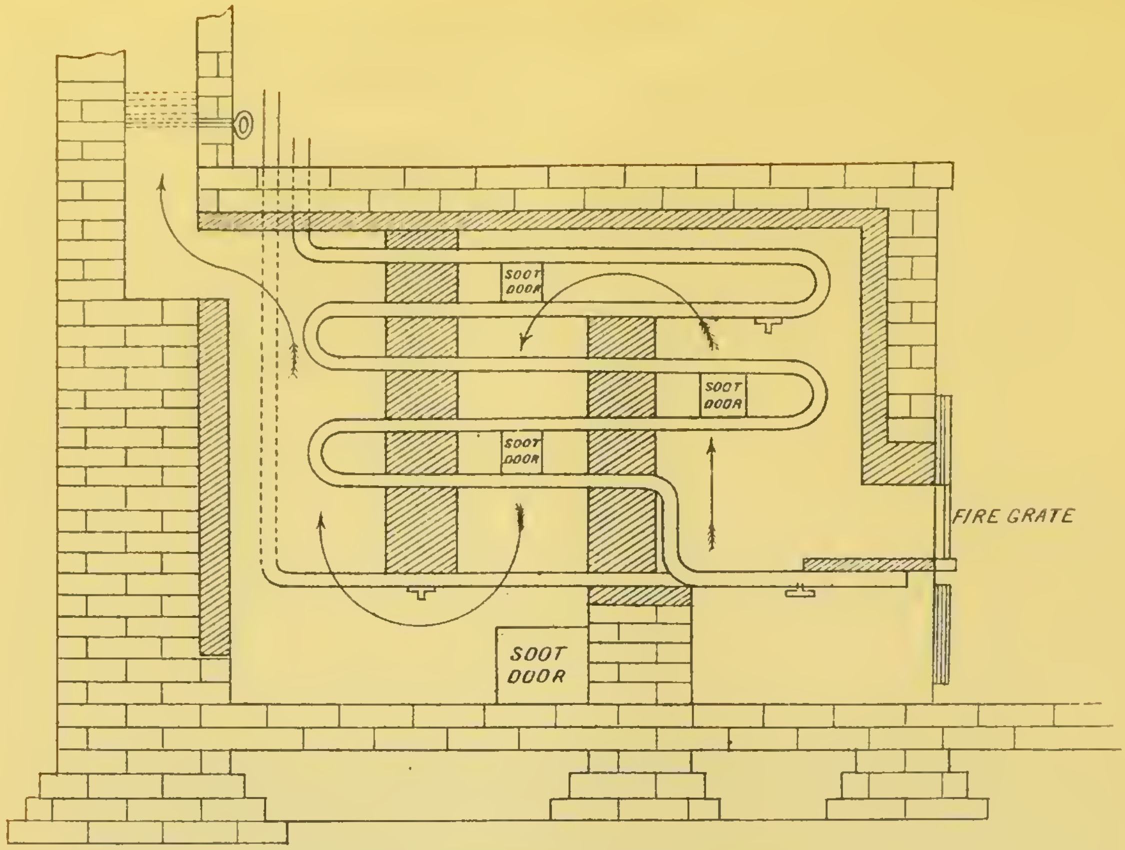
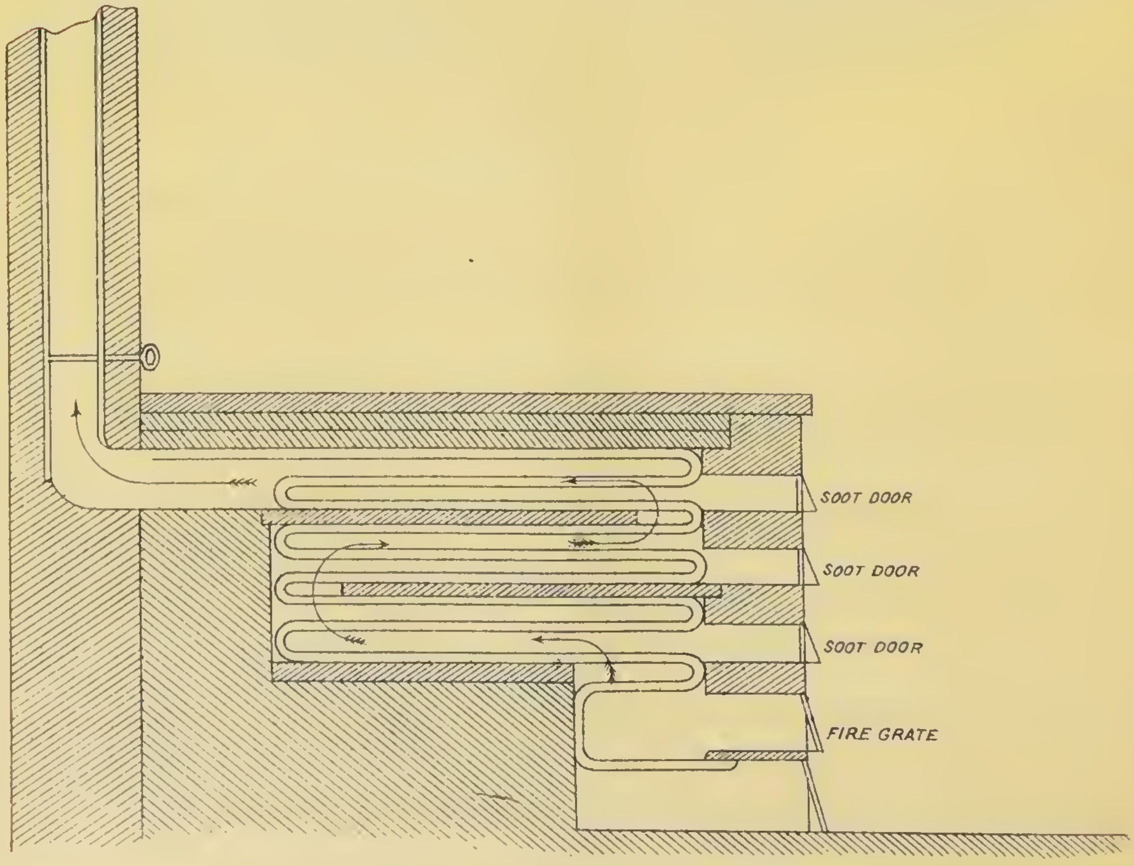


USUAL FORM OF FURNACE



FORM OF FURNACE SUGGESTED BY MR. LANGLANDS

Iron furnaces, though probably less expensive in first cost and more easily repaired, are not to be recommended, as they entail a considerable loss of heat by radiation. The only one used in the Dundee Board schools (viz., Butterburn) has been very unsatisfactory and costly in consumption of coal. The Aberdeen small hot-pipe schools, which are heated by iron furnaces, also seem to consume more coal than the corresponding schools in Dundee which are heated by brick furnaces.

IX. The air and heating-chambers, &c., should be arranged in the basement as represented in the preceding rough block plan.

The heating pipes might be distributed on the same plane over the air-chamber at a height of about 4 ft. from the ground. The air-chamber and other parts of the basement would be excavated to the depth of say seven feet. A wooden flap placed at *a* might be made to regulate the temperature of the air going to the rooms by being placed in such a position as to direct the incoming air as it leaves the fan above or below the hot pipes, as may be necessary. The shaded parts of the plan would not need to be excavated. The funnel-shaped mouth *a* on the inside of the fan has the effect of increasing the volume of air passing.

The walls ABCD should be of such a thickness as to allow all the inlet and outlet flues of the several rooms to lie in them flush, except those of the corner rooms, which would lie in the walls EA, FD, BG, and CH. By this means all the inlet flues would be as directly as possible over the fresh air-chamber; while the outlet flues would be as nearly as possible directly under the large Louvre outlet shafts on the roof, so that in this way a great economy in flues would be effected.

Such a school as the above would be arranged on the system of a central hall and staircases, with entrances at each end, and rooms along each side of the building, and also at each end in the upper flats.

X. There should be but one main inlet air-shaft, but of large size. It should be freely open at the top, and not fitted with Louvre boards.

XI. The incoming air should be filtered through coarse jute cloth placed diagonally across the large inlet flue, or across the air-chamber, and slightly inclined *towards* the current of air, so as to admit of being readily cleaned without being taken down.

XII. The fresh air inlet shafts in the several school-rooms should be much wider and shallower than is usually the case, so as to distribute the air in a thin stream, and with less risk of draught.

XIII. Schools should be built to accommodate not less than 1000 children, large schools being worked much more economically per head of accommodation than small ones, especially when mechanical ventilation is used.

XIV. Before *definite* conclusions can be drawn as regards the relative efficiency of the various natural systems, a large number of extensive and systematic observations of temperature must be made in the schools in Dundee fitted with the several different systems of heating.

Each room of certain selected schools should be provided with reliable and *previously-tested* thermometers, and readings made regularly at stated times every day for a period of several weeks, the observations in the several schools being made simultaneously. By this means we should also learn whether our small consumption of coal, compared with that in other towns, was keeping the children too cold, or was a really wise economy.

THOS. CARNELLEY.

APPENDIX I.

HEATING AND VENTILATING OF SCHOOLS.

[*Please fill in this form as far as possible, and oblige. In regard to the method of heating, it will be sufficient to strike out the item indicating the system of heating adopted in the school, giving in addition, however, the number of fires or stoves if such are used.*]

Name of School Board : ______________________

Name of School : ______________________

Year when opened by the Board : ______________________

Accommodation calculated to 8 sq. ft. per head : ______________________

Annual consumption of Coal in tons. (State if this includes Coals used in a caretaker's house : ______________________

Average price of Coals per ton : ______________________

Annual cost of Coals. (State if this includes Coals used in a caretaker's house):

____

State Method of Heating, such as :—

(1) Open Fires { *(a)* No. of Ordinary Grates. *(b)* No. of Manchester Grates.

(2) Stoves { *(a)* Kind of Stoves. *(b)* No. of Stoves.

(3) Large Hot-water Pipes (Low-pressure).

(4) Small Hot-water Pipes (High-pressure—Perkins' System).

(5) Low-pressure Steam Pipes.

(6) High-pressure Steam Pipes.

Method of Ventilating :—

N.B.—The above Returns should include all Departments of the School.

ANNUAL COST.

Town.	Mode of Heating.	No. of Schools	Average Accommodation per School.	Average No. of Fires per School.	Average No. of Pupils per Fire	Average Consumption of Coals. Per School.	Per Fire.	Per Head.	Average Price of Coals per ton.	Average Cost of Coals. Per School.	Per Fire.	Per Head.
						Tons.	Tons.	lbs.	s. d.	£ s. d.	s. d.	d.
Dundee	Open Fires	8	430	$5\frac{1}{3}$	80	$8\frac{1}{4}$	1·5	42	12 1	4 18 10	18 4	$2\frac{3}{4}$
N.V.	Large Hot-water Pipes (low pressure)	8	666	2	...	$15\frac{1}{4}$	...	51	12 1	9 4 4	...	$3\frac{1}{3}$
	Small Hot-water Pipes (high pressure)	5	814	1	...	19	...	52	11 $11\frac{1}{2}$	11 6 1	...	$3\frac{1}{3}$
M.V.	Ditto.	4	1279	6	...	53·3	...	93	11 1	29 12 0	...	$5\frac{1}{2}$
Aberdeen	Open Fires	12	620	$9\frac{1}{2}$	65	11·6	1·1	42	12 5	7 3 10	15 2	$2\frac{3}{4}$
N.V.	Small Hot-water Pipes (high pressure)	5	599	1	...	21·2	...	79	11 5	12 2 6	...	$4\frac{3}{4}$
	Ditto.	2	1315	5	...	33·2	...	57	11 5	19 0 0	...	$3\frac{1}{2}$
M.V.	Large Hot-water Pipes (low pressure)	1	663	5	...	27	...	91	11 5	15 8 0	...	$5\frac{1}{2}$
Edinburgh	Open Fires—											
	Ordinary Grates	5	747	14	53	29	2·0	86	11 0	15 15 0	22 6	5
	Manchester Grates	10	1092	18	60	36	2·0	74	11 0	19 15 6	21 10	$4\frac{1}{3}$
Greenock	Open Fires	8	634	...	...	19·6	...	69	9 $6\frac{3}{4}$	9 7 8	...	$3\frac{1}{2}$
	Large Hot-water Pipes (low pressure)	4	995	...	...	40	...	89	8 $10\frac{1}{2}$	17 12 4	...	$4\frac{1}{4}$
Newcastle	Open Fires	4	801	9	89	36·0	4·0	101	8 $11\frac{1}{2}$	16 2 2	35 9	$4\frac{3}{4}$
	Large Hot-water Pipes (low pressure)	6	1031	3	...	38·2	...	83	8 9	16 14 9	...	4
	Small Hot Steam Pipes and Coils (high pressure)	1	1153	3	...	42·7	...	83	8 9	18 13 0	...	4
Bradford	Large Hot-water Pipes (low pressure)	30	864 [1]	...	...	52·3	...	136	8 $9\frac{1}{2}$	23 1 1	...	$6\frac{1}{3}$
Leeds	Open Fires	15	910	$16\frac{1}{2}$	55	62·2	3·8	153	7 0	21 15 5	26 6	$5\frac{3}{4}$
	Open Fires and Stoves, in ratio of about 3 to 2	22	880	$14\frac{1}{2}$	60	43·5	3·0	110	7 0	15 3 2	20 9	4
	Large Hot-water Pipes (low pressure)	13	769	...	...	42·5	...	124	7 0	14 17 2	...	$4\frac{2}{3}$
Sheffield	Open Fires	2	900	...	...	67·5	...	168	10 9	36 6 0	...	$9\frac{2}{3}$
	Large Hot-water Pipes (low pressure)	3	900	...	...	62	...	154	10 9	33 6 6	...	9
	Small Hot-water Pipes (high pressure)	20	800	...	...	62	...	174	10 9	33 6 6	...	10
	High pressure Steam Pipes	3	1125	...	...	81·5	...	162	10 9	43 16 6	...	$9\frac{1}{3}$
Salford	Open Fires	7	481	$7\frac{1}{2}$	63	$22\frac{1}{2}$	3·0	104	8 3	9 5 2	24 5	$4\frac{2}{3}$
	Large Hot-water Pipes (low pressure)	5	507	2	...	$28\frac{1}{2}$	...	125	8 3	11 14 5	...	$5\frac{1}{2}$
	Hot Air	5	598	5	...	25	...	94	8 3	10 7 2	...	$4\frac{1}{4}$
	Mixed System of Open Fires, large Hot-water Pipes, and Hot Air	2	680	5	...	$25\frac{3}{4}$	...	85	8 3	10 13 7	...	$3\frac{3}{4}$
Nottingham	Open Fires	3	364 [1]	...	...	$31\frac{2}{3}$	...	195	7 0	11 1 10	...	$7\frac{1}{3}$
	Large Hot-water Pipes (low pressure) & Open Fires	4	895 [1]	...	...	$64\frac{3}{4}$	...	162	7 0	22 13 1	...	6
	Large Hot-water Pipes only (low pressure)	19	808 [1]	...	...	$63\frac{2}{3}$	...	175	7 0	22 5 5	...	$6\frac{2}{3}$
Northampton	Open Fires	2	951	$17\frac{1}{2}$	54	$45\frac{1}{2}$	2·6	107	13 0	28 18 10	33 1	$7\frac{1}{3}$
	Open Fires and Stoves, in ratio of 3 to 2	2	1101	$21\frac{1}{2}$	51	$43\frac{1}{2}$	2·0	88	12 11	28 7 6	26 5	$6\frac{1}{4}$
	Small Hot Pipes (high pressure)	1	1164	5	...	$56\frac{1}{2}$	...	108	12 6	35 6 9	...	$7\frac{1}{4}$
Birmingham	Large Hot-water Pipes (low pressure)	36	1120	...	...	$67\frac{3}{4}$	...	136	8 6	28 16 10	...	$6\frac{1}{4}$
Leicester	Stoves	8	853	11	74	42	3·4	111	10 0	21 3 9	34 7	6
	Large Hot-water Pipes (low pressure)	6	1021	...	...	40	...	86	10 0	19 13 4	...	$4\frac{2}{3}$
	Low pressure Steam Coils	1	1599	...	...	86	...	120	10 0	43 0 0	...	$6\frac{1}{2}$
Liverpool	Open Fires	4	1184	22	54	51	2·4	97	10 6	27 0 9	24 10	$5\frac{1}{3}$
	Large Hot-water Pipes (low pressure)	17	1268	...	...	64	...	114	10 0	31 18 3	...	6

Town.	Mode of Heating.	Cubic Foot of Gas per Engine. Per School.	Per Head.	Average Price of Gas.	Average Cost of Gas per Engine. Per School.	Per Head.	Average Cost of Engine Oil per School.	Average Cost of Repairs per School.	Average Total Cost. Per School.	Per Fire.	Per Head	Per 1000.
					£ s. d.	d.	£ s. d.	£ s. d.	£ s. d.	s. d.	d.	£ s. d.
Dundee	Open Fires	......	......	......	......	...	...	0 5 0	5 3 10	19 4	3	12 1 7
N.V.	Large Hot-water Pipes (low pressure)	......	......	......	......	...	...	0 5 0	9 9 4	...	$3\frac{1}{2}$	14 4 4
	Small Hot-water Pipes (high pressure)	......	......	......	......	...	...	0 5 0	11 11 1	...	$3\frac{1}{2}$	14 4 0
M.V.	Ditto.	66,800	52	3 8	12 5 5	$2\frac{1}{3}$	2 3 7	0 15 8	44 16 8	...	$8\frac{1}{2}$	35 0 11
Aberdeen	Open Fires	......	......	......	......	...	...	0 5 0	7 8 10	15 8	3	12 0 1
N.V.	Small Hot-water Pipes (high pressure)	......	......	......	......	...	...	0 5 0	12 7 6	...	5	20 10 0
	Ditto.	61,600	47	3 7	11 0 8	2	1 4 0	1 3 0	32 7 8	...	6	24 12 6
M.V.	Large Hot-water Pipes (low pressure)	Gals. water, 705,320	Gals. water, 1063	Price of water, 5d ℔ 1000 gals.	Cost of water, 14 14 0	$5\frac{1}{3}$	0 2 6	12 17 0	43 1 6	...	$15\frac{1}{2}$	64 15 10
Edinburgh	Open Fires— Ordinary Grates	......	......	......	......	...	...	0 5 0	16 0 0	22 8	$5\frac{1}{4}$	21 8 7
	Manchester Grates	......	......	......	......	...	...	0 5 0	20 0 6	22 1	$4\frac{1}{2}$	18 6 10
Greenock	Open Fires	......	......	......	......	...	...	0 5 0	9 12 8	...	$3\frac{2}{3}$	15 3 11
	Large Hot-water Pipes (low pressure)	......	......	......	......	...	...	0 5 0	17 17 4	...	$4\frac{1}{3}$	17 19 1
Newcastle	Open Fires	......	......	......	......	...	...	0 5 0	16 7 2	36 4	5	20 8 4
	Large Hot-water Pipes (low pressure)	......	......	......	......	...	...	0 5 0	16 19 9	...	4	16 9 5
	Small Hot Steam Pipes and Coils (high pressure)	......	......	......	......	...	...	0 5 0	18 18 0	...	4	16 7 10
Bradford	Large Hot-water Pipes (low pressure)	......	......	......	......	...	...	0 5 0	23 6 1	...	$6\frac{1}{2}$	26 19 5
Leeds	Open Fires	......	......	......	......	...	...	0 5 0	22 0 5	26 10	$5\frac{3}{4}$	24 4 0
	Open Fires and Stoves, in ratio of about 3 to 2	......	......	......	......	...	...	0 5 0	15 8 2	21 1	$4\frac{1}{4}$	17 10 2
	Large Hot-water Pipes (low pressure)	......	......	......	......	...	...	0 5 0	15 2 2	...	$4\frac{3}{4}$	19 12 11
Sheffield	Open Fires	......	......	......	......	...	...	0 5 0	36 11 0	...	$9\frac{3}{4}$	40 12 3
	Large Hot-water Pipes (low pressure)	......	......	......	......	...	...	0 5 0	33 11 6	...	9	37 6 1
	Small Hot-water Pipes (high pressure)	......	......	......	......	...	...	0 5 0	33 11 6	...	10	41 19 4
	High pressure Steam Pipes	......	......	......	......	...	...	0 5 0	44 1 6	...	$9\frac{1}{2}$	39 3 4
Salford	Open Fires	......	......	......	......	...	...	0 5 0	9 10 2	25 1	$4\frac{3}{4}$	19 15 3
	Large Hot-water Pipes (low pressure)	......	......	......	......	...	...	0 5 0	11 19 5	...	$5\frac{5}{8}$	23 12 2
	Hot Air	......	......	......	......	...	...	0 5 0	10 12 2	...	$4\frac{1}{4}$	17 14 9
	Mixed System of Open Fires, large Hot-water Pipes, and Hot Air	......	......	......	......	...	...	0 5 0	10 18 7	...	4	16 1 2
Nottingham	Open Fires	......	......	......	......	...	...	0 5 0	11 6 10	...	$7\frac{1}{2}$	31 3 3
	Large Hot-water Pipes (low pressure) & Open Fires	......	......	......	......	...	...	0 5 0	22 18 1	...	$6\frac{1}{4}$	25 11 10
	Large Hot-water Pipes only (low pressure)	......	......	......	......	...	...	0 5 0	22 10 5	..	$6\frac{2}{3}$	27 17 4
Northampton	Open Fires	......	......	......	......	...	..	0 5 0	29 3 10	33 4	$7\frac{1}{3}$	30 13 7
	Open Fires and Stoves, in ratio of 3 to 2	......	......	......	......	...	...	0 5 0	28 12 6	26 8	$6\frac{1}{4}$	25 19 9
	Small Hot Pipes (high pressure)	......	......	......	......	...	...	0 5 0	35 11 9	...	$7\frac{1}{3}$	30 11 6
Birmingham	Large Hot-water Pipes (low pressure)	......	......	......	......	...	...	0 5 0	29 1 10	...	$6\frac{1}{4}$	25 19 6
Leicester	Stoves	......	......	......	......	...	...	0 5 0	21 8 9	35 2	6	25 2 8
	Large Hot-water Pipes (low pressure)	......	......	......	......	...	...	0 5 0	19 18 4	...	$4\frac{2}{3}$	19 9 11
	Low pressure Steam Coils	......	......	......	......	...	...	0 5 0	43 5 0	...	$6\frac{1}{2}$	27 1 0
Liverpool	Open Fires	......	......	......	......	...	...	0 5 0	27 5 9	25 1	$5\frac{1}{2}$	22 19 2
	Large Hot-water Pipes (low pressure)	......	......	......	......	..	...	0 5 0	32 8 0	...	6	25 0 0

FIRST COST.

Town.	Mode of Heating.	Cost of Heating Apparatus. Per School.	Per Head.	Cost of Ventilating Apparatus. Per School.	Per Head.	Total Cost of Heating and Ventilating Apparatus. Per School.	Per Head.	Per 1000.	State of Air. Temperature F.	Carbonic Acid.	Organic Matter.	Micro-organisms.
		£ s. d.	s. d.	£ s. d.	s. d.	£ s. d.	s. d.	£ s. d.	Excess*	Total.	Total.	Total.
Dundee	Open Fires	50 4 2	1 7	25 6 10	0 $9\frac{2}{3}$	75 11 0	2 5	120 16 8	19·7	17·0	16·2	[illegible]
N.V.	Large Hot-water Pipes (low pressure)	179 10 3	5 $4\frac{3}{4}$	66 3 2	2 0	245 13 4	7 $4\frac{3}{4}$	368 18 10	14·1	20·9	19·3	[illegible]
	Small Hot-water Pipes (high pressure)	209 19 8	4 $7\frac{1}{4}$	58 9 4	1 $3\frac{1}{2}$	268 9 0	5 $10\frac{3}{4}$	294 15 10	13·8	17·7	11·2	[illegible]
M.V.	Ditto.	...	...	...	...	1489 0 0	23 3	1163 19 3	22	12·8	8·6	[illegible]
Aberdeen	Open Fires	...	...	...	...	907 0 0	10 0	500 0 0	14·6	17·7	...	[illegible]
N.V.	Small Hot-water Pipes (high pressure)	...	...	...	...	1065 0 0	11 7	582 0 0	...	...	...	[illegible]
	Ditto.	...	...	...	...	1508 0 0	16 6	826 0 0	15·6	16·2	...	[illegible]
M.V.	Large Hot-water Pipes (low pressure)	...	...	...	...	These figures represent the cost of applying the several systems to the Ashley Rd. School.		......	17·0	15·5	...	[illegible]
Edinburgh	Open Fires— Ordinary Grates	...	...	...	...	......	...	......	...	16·4	13·5	[illegible]
	Manchester Grates	...	...	...	...	......	...	......	...	13·6	8·3	[illegible]
Greenock	Open Fires	...	...	...	...	......	...	......	...	...	...	...
	Large Hot-water Pipes (low pressure)	...	...	...	...	......	...	......	...	...	...	...
Newcastle	Open Fires	...	...	...	...	......	...	......	15·5	14·7	4·5	[illegible]
	Large Hot-water Pipes (low pressure)	...	...	...	...	......	...	......	...	...	...	...
	Small Hot Steam Pipes and Coils (high pressure)	...	...	...	...	......	...	......	4·5	7·2	6·8	[illegible]

*Above outside air at same time.

(1) Official as recognised by the Department.

A. NATURALLY VENTILATED SCHOOLS.

MODE OF HEATING.	Town.	No. of Schools.	Average Accommodation	Average No. of Pupils per Fire.	Coal Consumed. Per Fire.	Coal Consumed. Per Head	Average Price of Coal.	Cost of Coal, including Repairs, &c. Per Fire.	Cost of Coal, including Repairs, &c. Per Head.	First Cost of Heating and Ventilation per Head.	State of the Air. Temperature (Excess).	State of the Air. Carbonic Acid (Total).	State of the Air. Organic Matter (Total).	State of the Air. Micro-organisms (Total).	Annual Cost. Taking Open Fires as Standard. Annual Consumption of Coal per Head.	Annual Cost. Taking Open Fires as Standard. Annual Total Cost per Head.	First Cost. Taking Open Fires as Standard.
					Tons.	Lbs.	S. D.	S. D.	D.	S. D.					Lbs.	D.	
Open Fires	Dundee	8	430	80	1·5	42	12 1	19 4	3	2 5	19·7	17·0	16·2	169	42	3	1
	Aberdeen	12	620	65	1·1	42	12 5	15 8	3	10 0	14·6	17·7	...	87	42	3	1*
	Greenock	8	634	...	...	69	9 $6\frac{3}{4}$	...	$3\frac{2}{3}$	...	...	...	...	...	42	3	...
	Edinburgh	15	977	58	2·0	77	11 0	22 4	$4\frac{2}{3}$	...	...	14·4	9·7	53	42	3	...
	Salford	7	481	63	3·0	104	8 3	25 1	$4\frac{3}{4}$	...	...	...	...	...	42	3	...
	Newcastle	4	801	89	4·0	101	8 $11\frac{1}{2}$	36 4	5	...	15·5	14·7	4·5	224	42	3	...
	Liverpool	4	1184	54	2·4	97	10 6	25 1	$5\frac{1}{2}$	...	...	...	...	...	42	3	...
	Leeds	15	910	55	3·8	153	7 0	26 10	$5\frac{3}{4}$	...	...	...	...	...	42	3	...
	Northampton	2	951	54	2·6	107	13 0	33 4	$7\frac{1}{3}$	...	...	...	...	...	42	3	...
	Nottingham	3	364	...	...	195	7 0	...	$7\frac{1}{2}$	...	...	...	...	...	42	3	...
	Sheffield	2	900	...	...	168	10 9	...	$9\frac{3}{4}$	...	...	...	...	...	42	3	...
		80	754	61	2·6	97	9 1	24 $0\frac{1}{4}$	$4\frac{3}{4}$	4 3	16·8	15·3	10·9	101	42	3	1
Large Hot-water Pipes (low pressure)	Dundee	8	666	...	...	51	12 1	...	$3\frac{1}{2}$	7 $4\frac{3}{4}$	14·1	20·9	19·3	96	51	$3\frac{1}{2}$	3
	Newcastle	6	1031	...	...	83	8 9	...	4	...	...	...	...	...	35	$2\frac{1}{2}$	...
	Greenock	4	995	...	...	89	8 $10\frac{1}{2}$	...	$4\frac{1}{3}$	...	...	...	...	...	54	$3\frac{1}{2}$	...
	Leicester	6	1021	...	...	86	10 0	...	$4\frac{2}{3}$	...	...	...	...	...	...	...	...
	Leeds	13	769	...	...	124	7 0	...	$4\frac{3}{4}$	...	...	...	...	...	34	$2\frac{1}{2}$	...
	Salford	5	507	...	...	125	8 3	...	$5\frac{2}{3}$	...	...	...	...	...	50	$3\frac{1}{2}$	...
	Liverpool	17	1268	...	...	114	10 0	...	6	...	...	...	...	...	49	$3\frac{1}{4}$	...
	Birmingham	36	1120	...	...	136	8 6	...	$6\frac{1}{4}$	...	...	...	...	...	...	...	...
	Bradford	30	864	...	...	136	8 $9\frac{1}{2}$	...	$6\frac{1}{2}$	...	...	...	...	...	...	...	...
	Nottingham	19	808	...	...	175	7 0	...	$6\frac{2}{3}$	...	...	...	...	...	38	$2\frac{2}{3}$	...
	Sheffield	3	900	...	...	154	10 9	...	9	...	...	...	...	...	$38\frac{1}{2}$	$2\frac{3}{4}$	...
		147	952	...	...	127	8 8	...	6	7 $4\frac{3}{4}$	14·1	20·9	19·3	96	40	$2\frac{9}{10}$	3
Small Hot-water Pipes (high pressure)	Dundee	5	814	...	...	52	11 $11\frac{1}{2}$	...	$3\frac{1}{2}$	5 $10\frac{3}{4}$	13·8	17·7	11·2	85	52	$3\frac{1}{2}$	$2\frac{1}{2}$
	Aberdeen	5	599	...	...	79	11 5	...	5	11 7	...	...	...	35	79	5	$1\frac{1}{6}$ *
	Northampton	1	1164	...	...	108	12 6	...	$7\frac{1}{3}$	...	...	...	...	...	$42\frac{1}{2}$	3	...
	Sheffield	20	800	...	...	174	10 9	...	10	...	...	...	...	...	$43\frac{1}{2}$	3	...
		31	781	...	...	138	10 $11\frac{1}{4}$	...	$8\frac{1}{4}$	6 $10\frac{1}{2}$	13·8	17·7	11·2	78	$50\frac{1}{2}$	$3\frac{2}{5}$	$1\frac{4}{5}$
Small Steam Pipes and Coils (high pressure)	Newcastle	1	1153	...	...	83	8 9	...	4	...	4·5	7·2	6·8	190	$34\frac{1}{2}$	$2\frac{1}{2}$	...
	Sheffield	3	1125	...	...	162	10 9	...	$9\frac{1}{2}$	...	...	...	...	...	$40\frac{1}{2}$	3	...
		4	1132	...	...	142	10 $5\frac{1}{2}$	...	8	...	4·5	7·2	6·8	190	39	$2\frac{9}{10}$	...
Open Fires and Stoves in ratio of 3 to 2	Leeds	22	880	60	3·0	110	7 0	21 1	$4\frac{1}{4}$	...	...	...	...	...	30	$2\frac{1}{4}$	...
	Northampton	2	1101	51	2·0	88	12 11	26 8	$6\frac{1}{4}$	...	...	...	...	...	$34\frac{1}{2}$	$2\frac{1}{2}$	...
		24	898	59	2·9	108	7 6	21 $10\frac{3}{4}$	$4\frac{3}{5}$	...	...	...	...	...	$30\frac{1}{2}$	$2\frac{3}{4}$	...
Hot Air	Salford	5	598	...	...	94	8 3	...	$4\frac{1}{4}$	...	...	...	...	...	38	$2\frac{3}{4}$	...
Low-pressure Steam Coils	Leicester	1	1599	...	...	120	10 0	...	$6\frac{1}{2}$	...	...	...	...	...	...	...	...

B. MECHANICALLY VENTILATED SCHOOLS.

MODE OF HEATING AND VENTILATING.	Town.	No. of Schools.	Average Accommodation	Annual Cost. Coal. Consumption per Head.	Coal. Price per Ton.	Coal. Cost per Head.	Gas for Engine. Consumption per Head.	Gas for Engine. Price per 1000 Cb. ft.	Gas for Engine. Cost per Head.	Cost of Oil for Engine and Repairs per Head.	Total Cost per Head.	First Cost of Heating and Ventilating per Head.	State of the Air. Temperature F. (Excess).	State of the Air. Carbonic Acid (Total).	State of the Air. Organic Matter (Total).	State of the Air. Micro-organisms (Total).	Annual Cost. Taking Open Fires as Standard. Annual Consumption of Coal per Head.	Annual Cost. Taking Open Fires as Standard. Annual Total Cost per Head.	First Cost. Taking Open Fires as Standard.
				Lbs.	S. D.	D.	Cb. ft.	S. D.	D.	D.	D.	S. D.					Lbs.	D.	
Mechanical Ventilation :— (a) By Gas Engine and small high-pressure hot-water Pipes	Aberdeen	2	1315	57	11 5	$3\frac{1}{2}$	47	3 7	2	$\frac{1}{2}$	6	16 6	15·6	16·2	...	7	57	6	$1\frac{2}{3}$*
	Dundee	4	1279	93	11 1	$5\frac{1}{2}$	52	3 8	$2\frac{1}{3}$	$\frac{2}{3}$	$8\frac{1}{2}$	23 3	22·0	12·8	8·6	13	93	$8\frac{1}{2}$	$9\frac{1}{2}$
		6	1291	81	11 2	$4\frac{2}{5}$	$50\frac{1}{2}$	3 $7\frac{3}{4}$	$2\frac{1}{4}$	$\frac{7}{12}$	$7\frac{1}{2}$	21 6	20·5	13·5	8·6	12	81	$7\frac{1}{2}$	7
(b) By Water Engine and large low-pressure hot-water Pipes	Aberdeen	1	663	91	11 5	$5\frac{1}{2}$	Water in gallons. 1063	5d. per 1000 gallons	$5\frac{1}{3}$	5	$15\frac{1}{2}$	...	17·0	15·5	...	10	91	$15\frac{1}{2}$	...

* These numbers represent the relative cost of applying the several systems to one and the same school, viz., Ashley Road.

APPENDIX IV.

THE VENTILATION OF SCHOOLS AS IT AFFECTS THE HEALTH AND EDUCATION OF THE CHILDREN.

I.—*Dundee Schools.*

ORDINARY SCHOOLS.	Percentage of Passes. Reading.	Writing.	Arithmetic.	Total.	Government Grant earned per head of Average Attendance.	Infectious Diseases.—Rate per 1000 of Average Attendance ¶. Measles.	Scarlet Fever.	Whooping Cough.	Total.	State of the Air. (Mean of numerous Analyses. [Carnelley, Haldane, and Anderson.] Carbonic Acid per 10,000.	Organic Matter.	Micro-organisms per litre.
Mechanically Ventilated :—												
Dundee High School	...	...	...	...	Not Grant Earning.	13	11	10	34 } av. 68	13·0	3·7	4
Harris Academy (Board School)	99·5	93·0	95·0	95·8	21/5 *	37	57	9	103	12·8	8·3	16
Naturally Ventilated :—												
Mean of all the other Board Schools, 18 in number	93·9 †	89·2 ‡	91·0 †	89·2 †	16/8	70	82	16	168	20·0	17·4	127
						For the year 1887 (a year of Epidemic).						

* The Grant in this School is much higher than in any one of the other Schools. † Only *one* of these Schools exceeds the Harris Academy. ‡ Four of these Schools exceed the Harris Academy. ¶ The Diseases Rates were obtained by an investigation of every individual case as to the School the child was attending at the time of taking the Disease. On this, as on several other occasions, I have been greatly indebted to Mr Kinnear, of our Sanitary Department, for so kindly furnishing me with the necessary data. § The actual number of cases of Infectious Diseases in the Works Schools were so few that no safe conclusion can be drawn either way, whilst the average attendance in some of these Schools is very small.

HALF-TIME WORKS SCHOOLS.	Percentage of Passes. Reading.	Writing.	Arithmetic.	Total.	Government Grant earned per head of Average Attendance.	Infectious Diseases.—Rate per 1000 of Average Attendance ¶ §. Measles.	Scarlet Fever.	Whooping Cough.	Total.	State of the Air. (Mean of numerous Analyses.) [Carnelley, Haldane, and Anderson.] Carbonic Acid per 10,000.	Organic Matter.	Micro-organisms per litre.
Mechanically Ventilated :—												
Ward Mills	...	...	...	...	24/7 *	108	101	40	249	10·8	9.8	28
Naturally Ventilated :—												
Mean of all other Works Schools, 7 in number	...	...	...	...	19/8	67	146	15	227	The Air in these Schools has not yet been examined, but will be this winter.		

II.—*Aberdeen Schools.*

	Percentage of Passes.															Government Grant earned per head of Average Attendance.	State of the Air.	
	Standard III.			Standard IV.			Standard V.			Standard VI.			Total III.—VI.				Carbonic Acid per 10,000 (Braizer).	Misro-organisms per litre (Thomson).
	R.	W.	A.	R.	W.	A.	R.	W.	A.	R.	W.	A.	R.	W.	A.			
Mechanically Ventilated:—																		
King Street School	99·4	98·7	93·0	98·5	98·0	93·6	97·7	94·7	96·2	98·3	100·0	88·3	98·7	97·8	95·3	22/2 *	15·5	9
Rosemount School †	100·0	100·0	86·5	100·0	94·6	84·2	100·0	97·5	94·9	100·0	95·6	73·3	100·0	97·8	86·0	20/11	...	5
Marywell Street School	100·0	100·0	100·0	100·0	100·0	97·5	100·0	94·2	91·3	100·0	92·9	92·9	100·0	97·7	96·0	20/3	15·4	10
Mean of all the above Schools	99·8	99·6	93·2	99·5	97·5	91·8	99·2	95·5	94·1	99·4	96·2	84·8	99·6	97·8	92·4	21/8	15·4	8
Naturally Ventilated:— Mean of all other Schools, 15 in number	95·2	93·6	89·9	97·5	96·2	88·4	94·3	79·1	75·0	97·1	88·9	78·0	95·6	90·4	84·2	19/6	22·2	61

* The Grant in this School is much higher than in any one of the 15 naturally ventilated Schools.

† The figures for this School represent the first year's work, for the School was only opened in 1887, and therefore had scarcely had time to get into full working order; hence the comparatively low results in some cases.

	Grant per Head.	
	S.	D.
Naturally Ventilated:—		
Mean of 4 Schools provided with outlet shafts, running from floor to roof, Tobin's tubes, &c., and comparatively well ventilated	19	$7\frac{1}{2}$
Mean of 11 Schools ventilated in the ordinary way, and so less satisfactory	19	$0\frac{1}{2}$

III.—*Edinburgh Schools.*

		State of the Air (Burton) (mean of numerous experiments).		
		Carbonic Acid per 10,000.	Organic Matter.	Micro-org per lit
Class A	Mean of 10 schools heated with Manchester grates, and ventilated by warm fresh air inlet flues from behind fire, and Tobin's tubes and proper outlets	13·4	8·3	47
Class B	Mean of 7 schools heated with ordinary grates, and ventilated in the ordinary way - - -	17·0	14·1	66

		Percentage of Passes.				Government Grant per H		
		R	W	A	Total.	Infants.	Juveniles.	To
						S. D.	S. D.	S.
Under Old Code of 1885	4 schools of Class A	93·0	90·1	90·4	91·2	14 7	19 4	18
	5 schools of Class B	92·7	92·7	88·1	90·4	14 10	18 10	17
Under New Code of 1886	6 schools of Class A	93·9	86·4	91·0	90·5	14 1	20 6	18
	2 schools of Class B	86·2	85·2	84·4	85·3	13 11	19 0	17

N.B.—The Grant per head in only one of the schools ventilated in the ordinary way comes up to the mean of the other schools, and even that school is in part heated by Manchester grates, and partly provided with Tobin's tubes and proper outlets.

IV.—*Govan Schools.*

	Government Grant per head. S. D.
Mechanically ventilated—	
Hillhead Board School - - - - - -	20 3 *
Naturally ventilated—	
Mean of all the other Board Schools, 17 in number -	17 2

V.—*Accrington Schools* (Lancashire).

	Grant per head (1886). S. D.
Mechanically ventilated—	
New Jerusalem British Schools, Hargreave Street -	19 11½
Naturally ventilated—	
Mean of all other Schools, 15 in number † - -	19 0

VI.—*Finchley Schools.*

	Grant per Head (1887).		Grant per Head (1888).	
Mechanically Ventilated :—				
East End—Long Lane . .	19/10	Mean 18/10¼	19/11¼	Mean 19/5
North End—Albert Street .	17/10½		18/11	
Naturally Ventilated :—				
St. Mary's	21/9¼	16/4¾	No returns to hand.	
East End	14/4¾			
Christ Church	13/0½			

* The grant in this school is much higher than in any one of the other schools.

† Only two of these schools earn as large a grant as the mechanically ventilated school, viz. 20s. 10d. and 22s. 5d. respectively.

VII.—*Birmingham Schools.*

Board Schools.	Government Grant per Head.				Percentage of Passes.							
					Boys.				Girls.			
	Infants.	Girls.	Boys.	Boys.	R.	W.	A.	Total.	R.	W.	A.	Total.
			Not including Drawing.	Including Drawing.								
Mechanically Ventilated:— Barford Road School (only been open one year)	s. d. 17 0	s. d. 20 8	s. d. 20 11	s. d. 22 5	98·6	95·5	95·0	96·0	97·1	98·3	99·4	98·0
Naturally Ventilated:— Mean of all other Schools (26 to 35 in number)	15 11¼ [1]	19 9½ [2]	20 1¼ [3]	21 3½ [4]	94·4 [5]	91·5 [6]	89·4 [7]	91·8 [5]	95·1 [8]	88·5 [9]	84·4 [10]	89·3 [10]

[1] Not one of these Schools exceeds 17s. per head.
[2] Two of these Schools are equal to Barford Road and four slightly exceed it, viz. 20s. 8½d., 20s. 9¼d., 20s. 11d., and 21s. 1d.
[3] Eleven of these Schools exceed Barford Road.
[4] Only two of these Schools earned as much as Barford Road, viz. 22s. 6½d. and 22s. 7¾d. respectively.
[5] Only two of these are as high as Barford Road.
[6] Only five ,, ,, ,,
[7] Only three ,, ,, ,,
[8] Only seven ,, ,, ,,
[9] Only one ,, ,, ,,
[10] None ,, ,, ,,

Note.—In the naturally ventilated Schools the returns are made out for Boys, Girls, and Infants, whereas in the Barford Road Schools they are made out for Seniors, Juniors, and Infants. In the above table, therefore, the Boys and the Girls in the naturally ventilated Schools have been respectively compared with the Seniors and Juniors in the Barford Road Schools.

VIII.—*Comparison of Mechanically Ventilated Schools.*

	Grant earned per head.	Volume of air supplied per hour per head of accommodation.	No. of minutes required to change the whole air of the school once.
	s. d.		
King Street (Aberdeen) -	22 2	777 cb. ft.	$8\frac{1}{2}$
Harris Academy (Dundee) -	21 5	659 „	11
* { Rosemount (Aberdeen) -	20 11	876 „	$7\frac{3}{4}$
* { Hillhead (Govan) - -	20 3	633 „	$9\frac{3}{4}$
Marywell Street (Aberdeen)	20 3	491 „	16

* Both these are new schools, and had only been open one year, and had therefore scarcely had time to get into full working order.

APPENDIX V.

Table showing the Effect of Washing the Floor of the School-rooms.

	Micro-organisms per Litre of Air.		The Floors of the Schools are washed every—
	Naturally Ventilated Schools.	Mechanically Ventilated Schools.	
Newcastle Board Schools [1] -	188	—	2 months.
Dundee „ „ [2] -	127	16	3 months.
Aberdeen „ „ [3] -	61	8	3 weeks.
Edinburgh „ „ [4] -	54	—	2 weeks.

[1] Calculated from the analyses of Bedson and Lovibond.
[2] „ „ „ Carnelley, Haldane, and Anderson.
[3] „ „ „ Thomson.
[4] „ „ „ Burton.

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